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WELCOME

ISSUE 130

This issue marks the tenth anniversary of **All About Space**. Launched in 2012 by Editor-in-Chief Dave Harfield before later being managed by Ben Biggs, I took the helm in 2015 after joining in 2013, and I'm delighted to be taking care of the magazine as it reaches such an important milestone. We couldn't let this occasion pass by unnoticed, so you'll see that **All About Space** has had a redesign for a slicker, cleaner-looking magazine. Your favourites – as requested by you – are still here, so you can enjoy the regulars from one month to the next.

From Mysteries of the universe to Ask Space, there's plenty to keep you entertained. As always, there are some new and exciting features for you to enjoy: we provide tips and advice on buying a telescope – and when the best time is – the biggest space news and images and so much more. We're also treating you to free copies of some of our sister titles, **All About History**, **History of War** and **How It Works**... turn to page 79 to download them now.

I'll see you next time – don't forget to drop me a line to let me know what you think of the refresh, and enjoy the new-look issue!

GEMMA LAVENDER
Content Director

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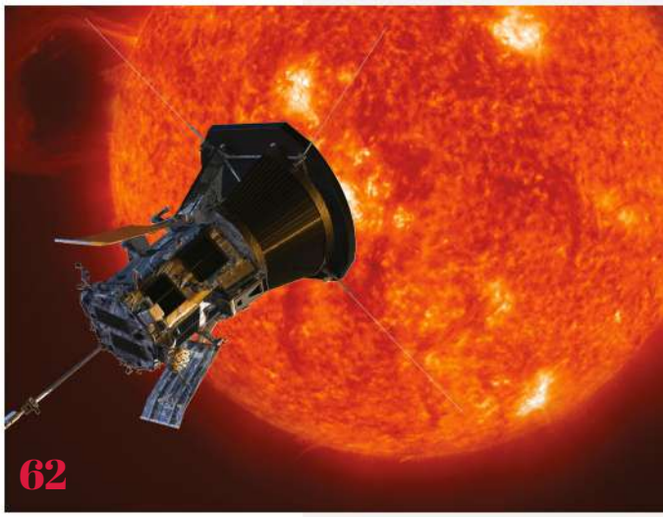

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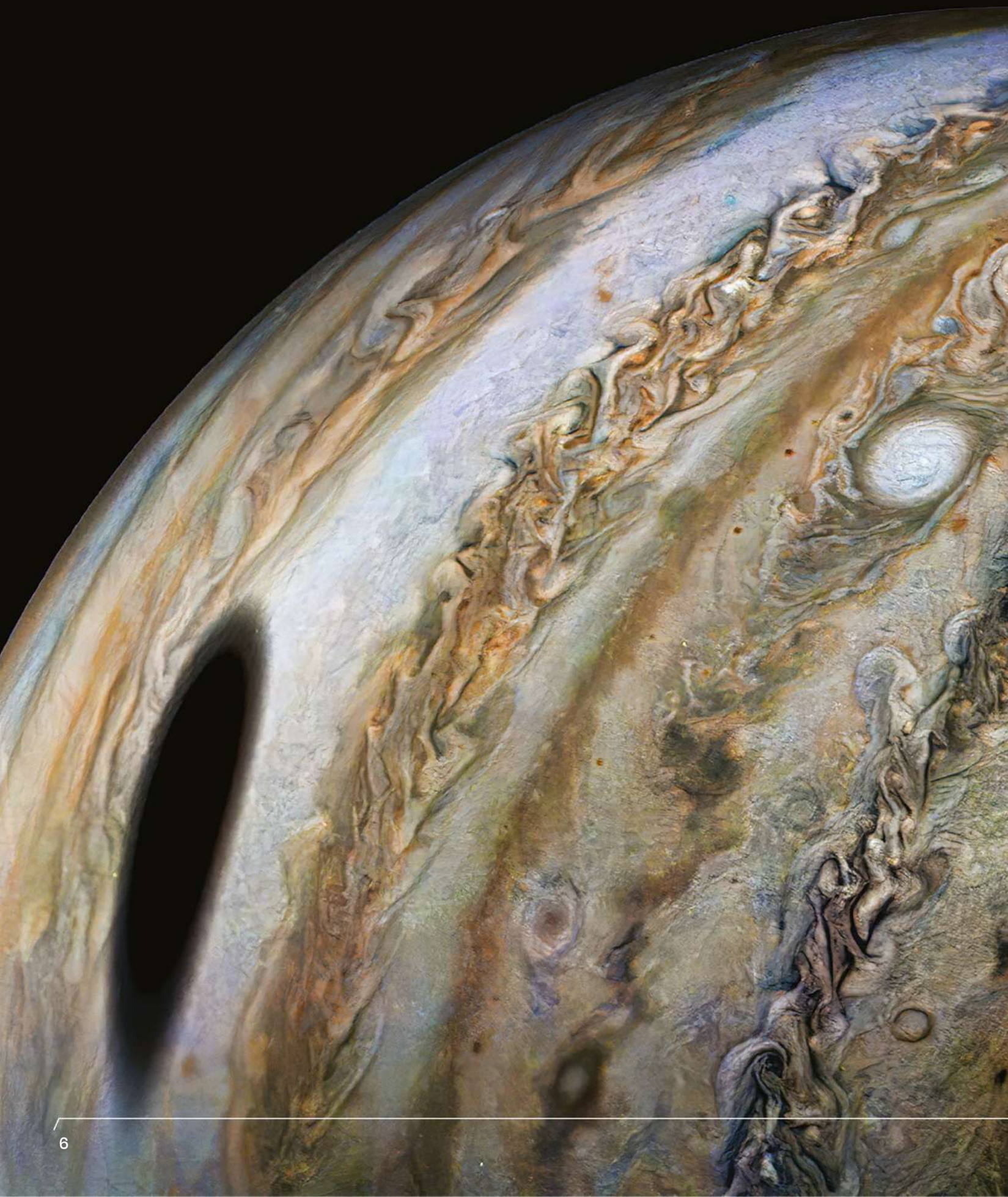
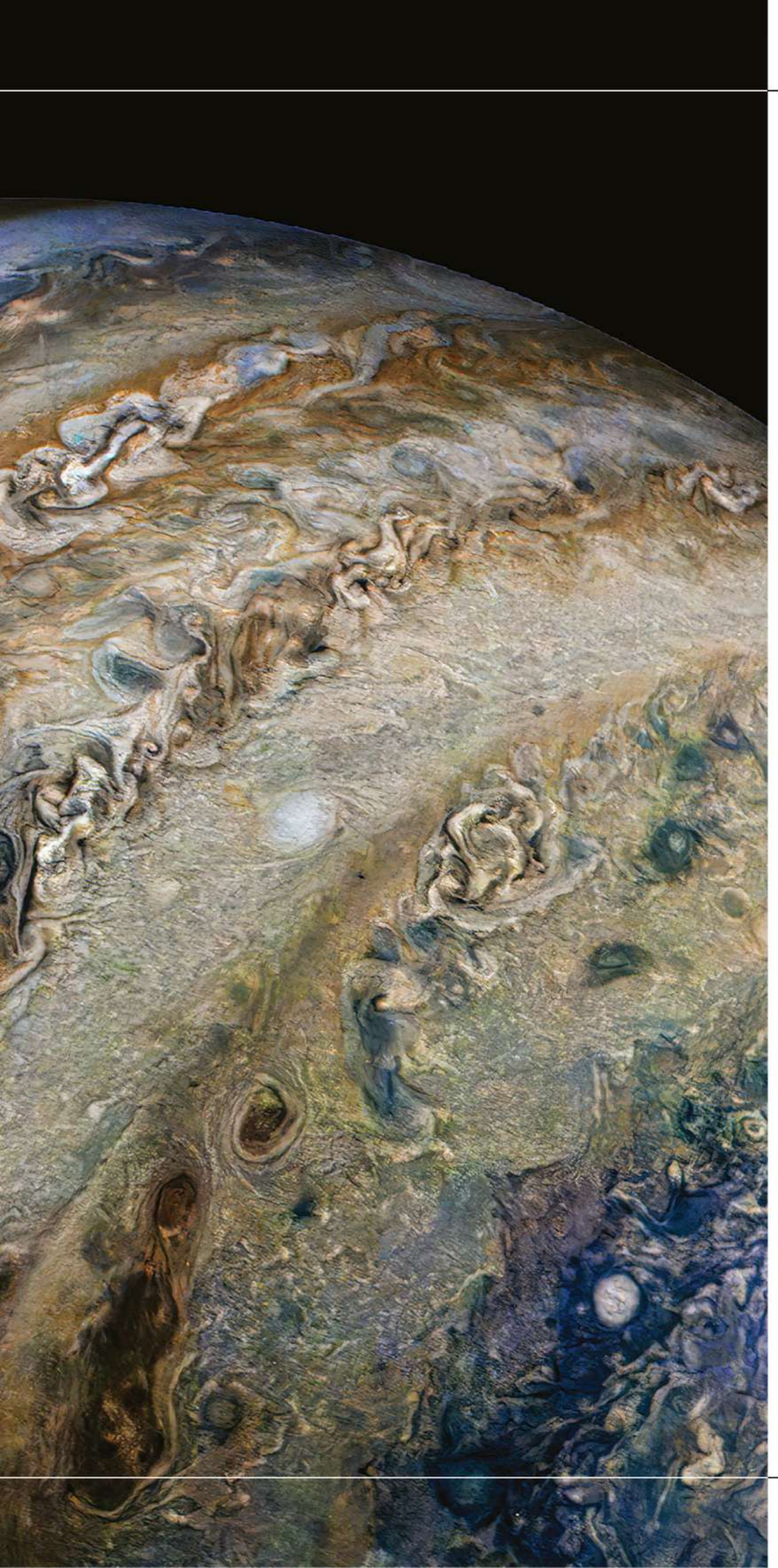




25 February 2022

Shadow of Jupiter's moon

Giant Jupiter and the shadow of its biggest moon Ganymede dominate the view in this latest image from the system. NASA's Juno mission whizzed close to the radiation-spewing planet for the 40th time on 25 February, with the resulting raw images of the encounter beamed home to Earth. Once there, citizen scientist Thomas Thomopoulos created this stunning view based on what was seen by the JunoCam instrument.

Juno was flying roughly 71,000 kilometres (44,000 miles) above Jupiter's cloud tops during the encounter, which is roughly 15 times closer than Ganymede's orbital distance of 1.1 million kilometres (666,000 miles).

If an observer could brave the radiation to float within the oval seen in the picture, that person would experience a total eclipse of the Sun. Total eclipses are more common on Jupiter than Earth, since the gas giant has many more moons. The planet hosts four large moons – Ganymede, Io, Europa and Callisto – that orbit closer to the plane of Jupiter than our own singular Moon. JunoCam captured this image from very close to Jupiter, making Ganymede's shadow appear especially large.

© NASA/JPL-Caltech

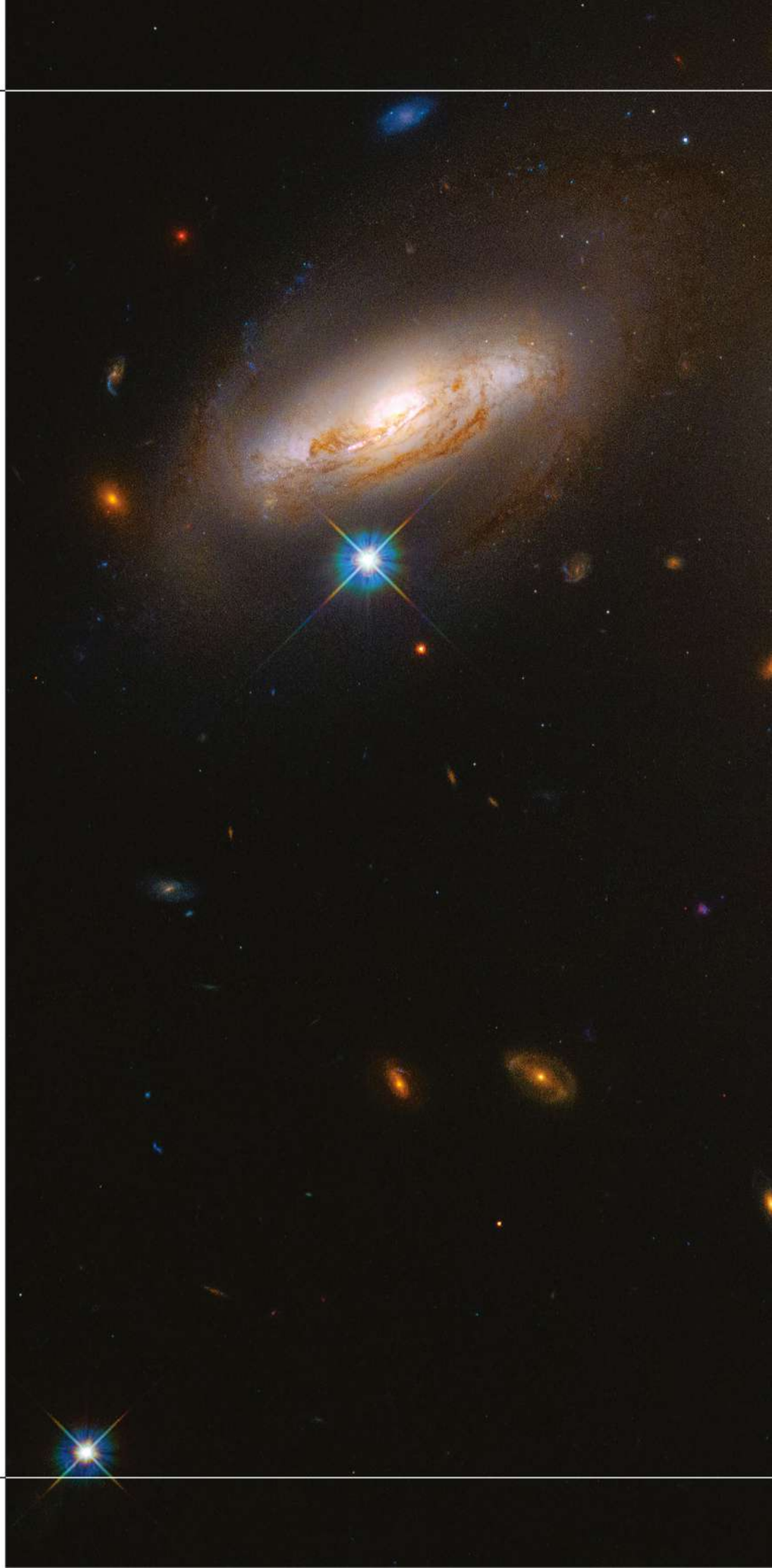
19 April 2022

Hubble celebrates 32nd anniversary

The Hubble Space Telescope captured an image of a unique group of merging galaxies that provides a glimpse into processes in the early universe. The five galaxies, known as Hickson Compact Group 40 (HCG 40), are in the process of merging into a single entity, a process that will be complete roughly a billion years from now. The image was released in anticipation of the venerable telescope's 32nd anniversary on 24 April and is part of Hubble's long-standing work in studying galactic evolution.

"Studying nearby groups like HCG 40 helps astronomers learn about how galaxies formed," the Hubble team said. "Tight groups like this may have been more common in the early universe, when their superheated, infalling material may have fuelled very energetic black holes called quasars."

The galaxy group, located some 300 million light years away from Earth, is very tightly packed into a region of space less than twice the diameter of the stellar disc of our own galaxy, the Milky Way. Although scientists have discovered more than 100 compact galaxy groups, the configuration of HGC 40 is rather unique as the galaxies are not part of a larger galaxy cluster, making them an interesting target for astronomers to study. How this configuration came into being is still a matter of debate.



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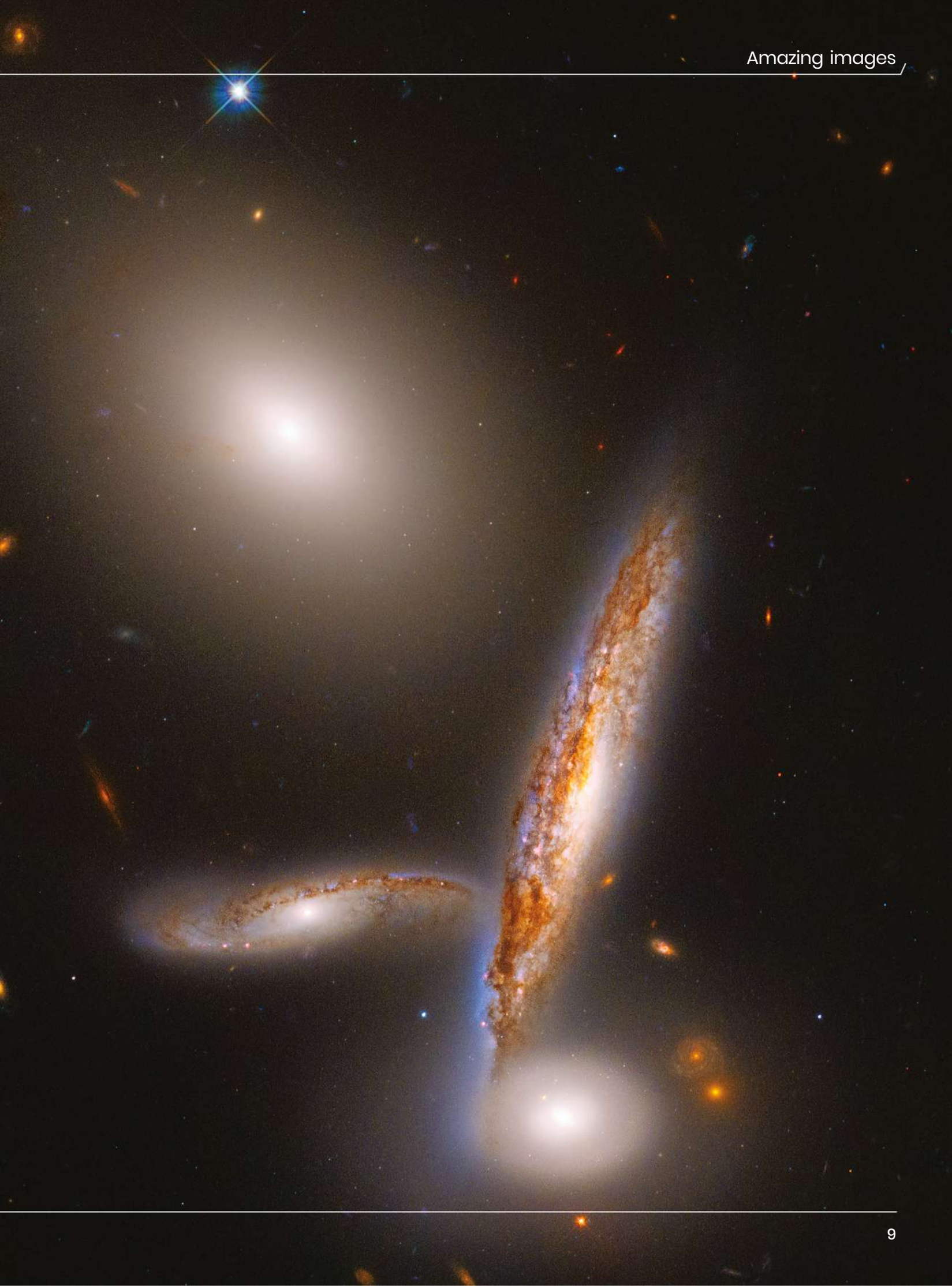
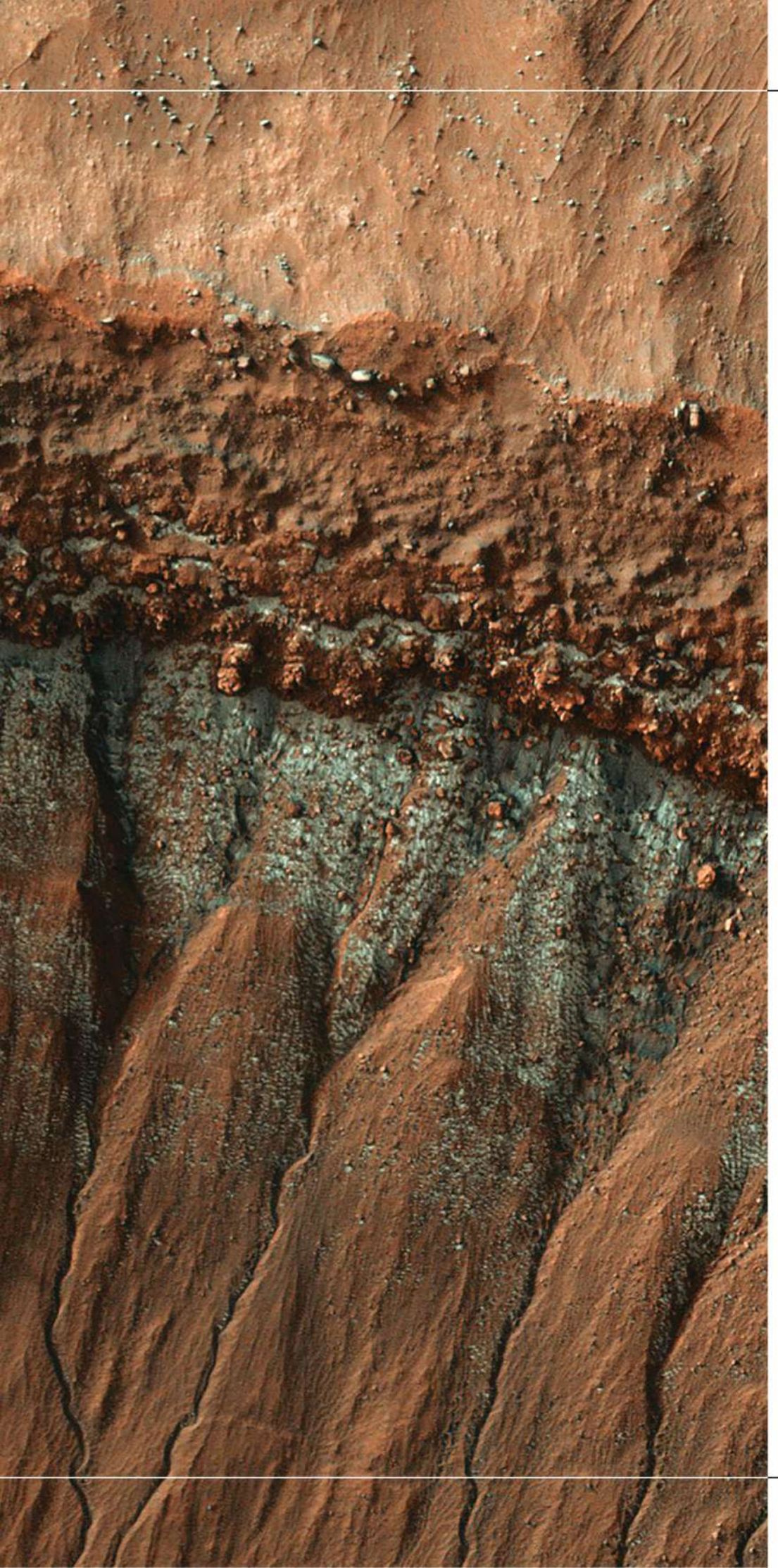




18 March 2022

As cool as ice

Frost extends across the surface of a southern crater on Mars in a new photo of the Red Planet. The High Resolution Imaging Science Experiment (HiRISE) onboard NASA's Mars Reconnaissance Orbiter (MRO) captured this image of Mars' frosty surface. Winters on Mars can be very cold, with temperatures near the poles dropping to -125 degrees Celsius (-195 degrees Fahrenheit). In turn, a layer of carbon dioxide frost, or dry ice, may form on the surface of some areas of the planet.

By the middle of Mars' four-month winter, frost can spread from the poles down to the middle latitudes of the planet, or about 50 degrees latitude, where it starts to melt under the warm rays of the Sun. This is equivalent to about the latitude of southern Canada on Earth.

But orbiters can also spot small patches of frost on pole-facing slopes closer to the equator. These locations experience colder temperatures because they receive less sunlight, meaning the carbon dioxide frost doesn't melt. The HiRISE photo was taken of Mars' southern hemisphere during the middle of winter. The photo captures a crater located near 37 degrees south latitude.

The south-facing slope of the crater is sprinkled with a bright frost of carbon dioxide, which appears blue in the enhanced colour photo from the orbiter. The photo revealed dry ice in and around gullies on the slope, which have been carved out by debris flows that occur during the warmer months.

© NASA/JPL-Caltech

Meteorites could have brought DNA to Earth

Reported by Charles Q. Choi

Key building blocks of DNA have been found in space rocks, suggesting cosmic impacts might have helped deliver these vital ingredients of life to ancient Earth.

DNA is made of four main building blocks: adenine (A), thymine (T), cytosine (C) and guanine (G). RNA also uses A, C and G, but swaps out thymine for uracil (U). Scientists wondering whether meteorites might have delivered these compounds to Earth have looked for nucleobases in space rocks, but until now scientists had only detected A and G in space rocks, and not T, C or U.

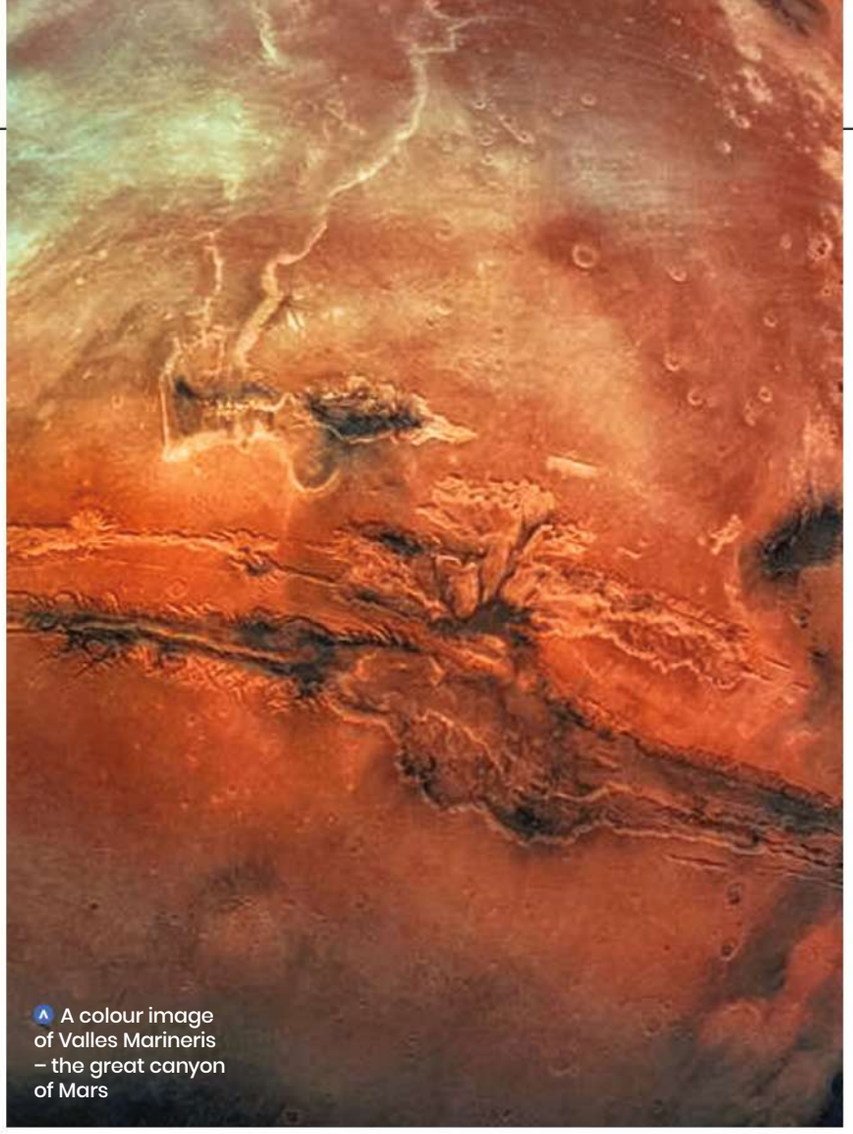
Nucleobases have two flavours: purines and pyrimidines. The nucleobases previously seen in meteorites are both purines, which are each made of a hexagonal molecule fused with a pentagonal molecule. The ones missing until now are pyrimidines, smaller structures each made of just a hexagonal molecule. It was a mystery why only purines were seen in meteorites. Prior lab experiments simulating conditions in outer space suggested that both purines and pyrimidines could have formed during light-triggered chemical reactions within interstellar molecular clouds, and that the compounds could then have been incorporated into asteroids and meteorites during the formation of the Solar System. Such chemical reactions may have also happened directly within the space rocks.

Now scientists have finally detected all the pyrimidines and purines found in DNA and RNA in meteorites that made it to Earth. "The presence of the five primary nucleobases in meteorites may have a contribution to the emergence of genetic functions before the onset of life on the early Earth," study lead author Yasuhiro Oba, an astrochemist at Hokkaido University in Japan, said.

Researchers employed state-of-the-art analytical techniques to detect tiny amounts of nucleobases, down to the range of parts per trillion – more sensitive than prior methods that attempted to detect pyrimidines in meteorites. The scientists analysed samples from three carbonaceous meteorites that prior work suggested could have hosted the kinds of chemical reactions that created nucleobases: the Murchison, Lake Murray and Tagish Lake meteorites.

They detected T, C and U at levels of up to a few parts per billion within the meteorites, present at concentrations similar to those predicted by experiments replicating the conditions that existed prior to the formation of the Solar System. In addition to the crucial T, C and U compounds, the scientists also detected other pyrimidines not used in DNA or RNA that further show meteorites' ability to carry these compounds.

< In this conceptual image of meteoroids delivering nucleobases to ancient Earth, the nucleobases are represented by structural diagrams with hydrogen atoms as white spheres, carbon as black, nitrogen as blue and oxygen as red



A colour image of Valles Marineris – the great canyon of Mars

Two giant marsquakes rock Mars' far side

Reported by Scott Dutfield

NASA's InSight lander touched down on Mars in November 2018 carrying the most sensitive seismometer ever designed. Since the mission's arrival at the Red Planet, it has detected countless seismic events, dubbed marsquakes, using the signals to map the planet's interior. But the two newly announced quakes, classified as S0976a and S1000a, were something special. "Not only are they the largest and most distant events by a considerable margin, S1000a has a spectrum and duration unlike any other event previously observed," said Anna Horleston, a seismologist at the University of Bristol. "They truly are remarkable events in the Martian seismic catalogue."

The first seismic event, S0976a, was of magnitude 4.2 and occurred on 25 August 2021, originating in Valles Marineris, a vast network of canyons that extends for 4,000 kilometres (2,500 miles) on the opposite side of the planet to InSight. Valles Marineris is what scientists call a graben system – a valley with distinct fault blocks that are relatively lower than the blocks on either side of them. The Martian canyon complex is one of the largest such systems in the entire Solar System. Although previous orbital imagery of Valles Marineris had identified the aftermath of seismic activity on Mars, such as faults and landslides, the 2021 detection is the first time an event has been recorded at this location. The second marsquake, S1000a, occurred 24 days later on 18 September 2021. This event was slightly smaller at magnitude 4.1. The second marsquake's exact point of origin remains unknown, though scientists have isolated it to the far side of Mars. S1000a also lasted for 94 minutes – the longest seismic event ever recorded on Mars.

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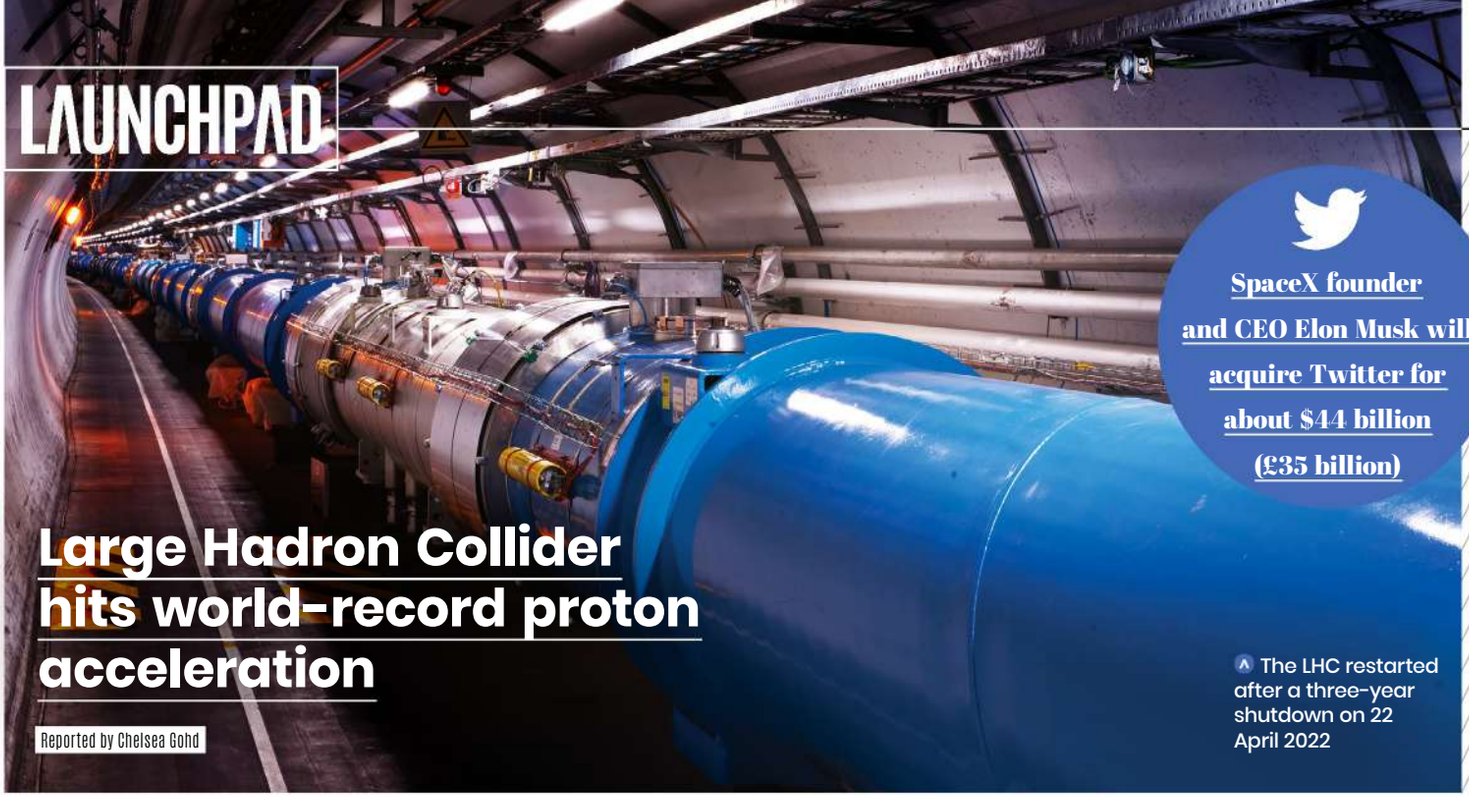

SpaceX founder and CEO Elon Musk will acquire Twitter for about $44 billion (£35 billion)

Large Hadron Collider hits world-record proton acceleration

Reported by Chelsea Gohd

The LHC restarted after a three-year shutdown on 22 April 2022

The newly upgraded Large Hadron Collider (LHC) just broke a world record with its proton beams. The LHC, located at CERN near Geneva, Switzerland, restarted on 22 April after a planned three-year hiatus, during which a number of upgrades were made to the facility. These improvements are already being put to the test. In restarting and preparing for its new operating phase, called Run 3, the LHC has already beaten a previous record. This particle accelerator is both the largest and most powerful in the world, and in a test run conducted shortly after being switched back on, the LHC accelerated beams of protons to a higher energy than ever before.

"Two LHC pilot beams of protons were accelerated to the record energy of 6.8 TeV per beam. This operation is part of the activities to recommission the machine in preparation of LHC Run 3, planned for the summer of 2022," CERN tweeted. With the upgrades implemented during shutdown, the energy of the LHC's proton beams was set to increase from 6.5 to 6.8 teraelectronvolts (TeV). For reference, one teraelectronvolt is equivalent to 1 trillion electron volts – in terms of kinetic energy that's roughly equal to the energy of a mosquito flying. While this might seem like a very small amount of energy, for a single proton it's an incredible amount of energy. The LHC is used to explore cosmic mysteries ranging from investigating possible candidates for dark matter to breaking apart our understanding of physics.

Overlooked gravitational-wave signals point to 'exotic' black holes

Reported by Stefanie Waldek

In a new analysis of gravitational-wave data, scientists with the international LIGO-Virgo Collaboration (LVC) have discovered ten new examples of merging binary black holes. Over the past seven years, the researchers have observed 90 gravitational-wave signals – ripples in the space-time continuum that indicate cataclysmic events such as black hole mergers, the research team said. They originally detected 44 such mergers during a six-month observational period in 2019, but a second look at the data using a different methodology revealed ten additional ones.

These newly detected mergers suggest "exotic astrophysical scenarios" that can be studied only through the gravitational waves that emanate from them, those behind the detections argue. For instance, one of the mergers appears to be a never-before-observed type of system in which a heavy black hole is consuming a smaller black hole that had been orbiting it in the opposite direction of its own spin. The discovery of the new mergers fills gaps in existing black hole data, as some of the black holes have higher or lower masses than are predicted by widely accepted nuclear physics models.

An artist's depiction of binary black holes

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ARE WE IN A CHAOTIC UNIVERSE?

Do we finally have a handle on chaos theory and how it influences the world around us?

Reported by Colin Stuart

When it comes to surviving in space, the tiniest things can be the difference between life and death. As Canadian astronaut Chris Hadfield said: "An astronaut who doesn't sweat the small stuff is a dead astronaut." That may be the case for human space travel, but astronomers are increasingly suspecting that the same mantra also applies to the wider universe. When it comes to the cosmos, it seems chaos theory is king.

Chaos theory traces its origins back to the 19th century. French polymath Henri Poincaré was attempting to win a prize of 2,500 crowns – a third of a professor's yearly salary – offered up by King Oscar II of Sweden and Norway to celebrate his 60th birthday. To win you had to predict the orbits of the planets. Isaac Newton's work on gravity allows you to foretell the future positions of two gravitationally intertwined objects with clockwork precision. Yet throw a third object into the mix and that ability vanishes. Poincaré failed to solve this 'three-body problem', but was awarded the prize nonetheless for important insights into why it's such a thorny conundrum to crack.

© Tobias Roetsch

Russian mathematician Sofya Kovalevskaya also carried out important work on the problem. The puzzle is difficult because even the smallest changes in a system with many moving parts can lead to huge differences later down the line. That, in a nutshell, is the essence of chaos theory. "We wouldn't have chaos theory if we didn't study planetary orbits," says Dr Paul Sutter of the Flatiron Institute in New York.

American mathematician and meteorologist Edward Lorenz compared it to the flap of a seagull's wing affecting the weather. He later switched to a butterfly, and to this day it's known as the 'butterfly effect'. In the 1960s Lorenz was using computers to try and predict weather patterns on Earth, but he found the outcome was wildly different even though it looked as if he was modelling the same situation each time. Investigation revealed that tiny rounding errors in the values fed into the computer blew up into major differences in the predicted forecast. Today Lorenz gets the lion's share of the credit, but Mary Cartwright and John Littlewood also analysed chaotic patterns in radio signals during World War II. To this day chaos theory places a limit on how far into the future we can accurately predict the weather. Chaos theory makes meteorology an imperfect science.

French mathematician Henri Poincaré was one of the first to grapple with chaos theory

Mathematicians have been studying chaos theory ever since Lorenz's insights. Somewhat counterintuitively, they have found that chaotic systems are not as unpredictable as they first seem. "It helps us to identify patterns, key elements, hidden rhythms and orders in systems that are not normally apparent," says Sutter. Period doubling is just one example. In a chaotic system, the time it takes for a pattern of

APPLYING CHAOS TO THE WEATHER

The mind-bending theory helps us get more of a handle on our planet's complex atmosphere

1 Our complex systems

Earth's weather systems are incredibly complex, with many different particles interacting in a variety of ways.

2 Jet streams

These fast-moving channels of air affect the weather in different parts of the world depending on their speed, latitude and movement.

3 Chaos solves weather

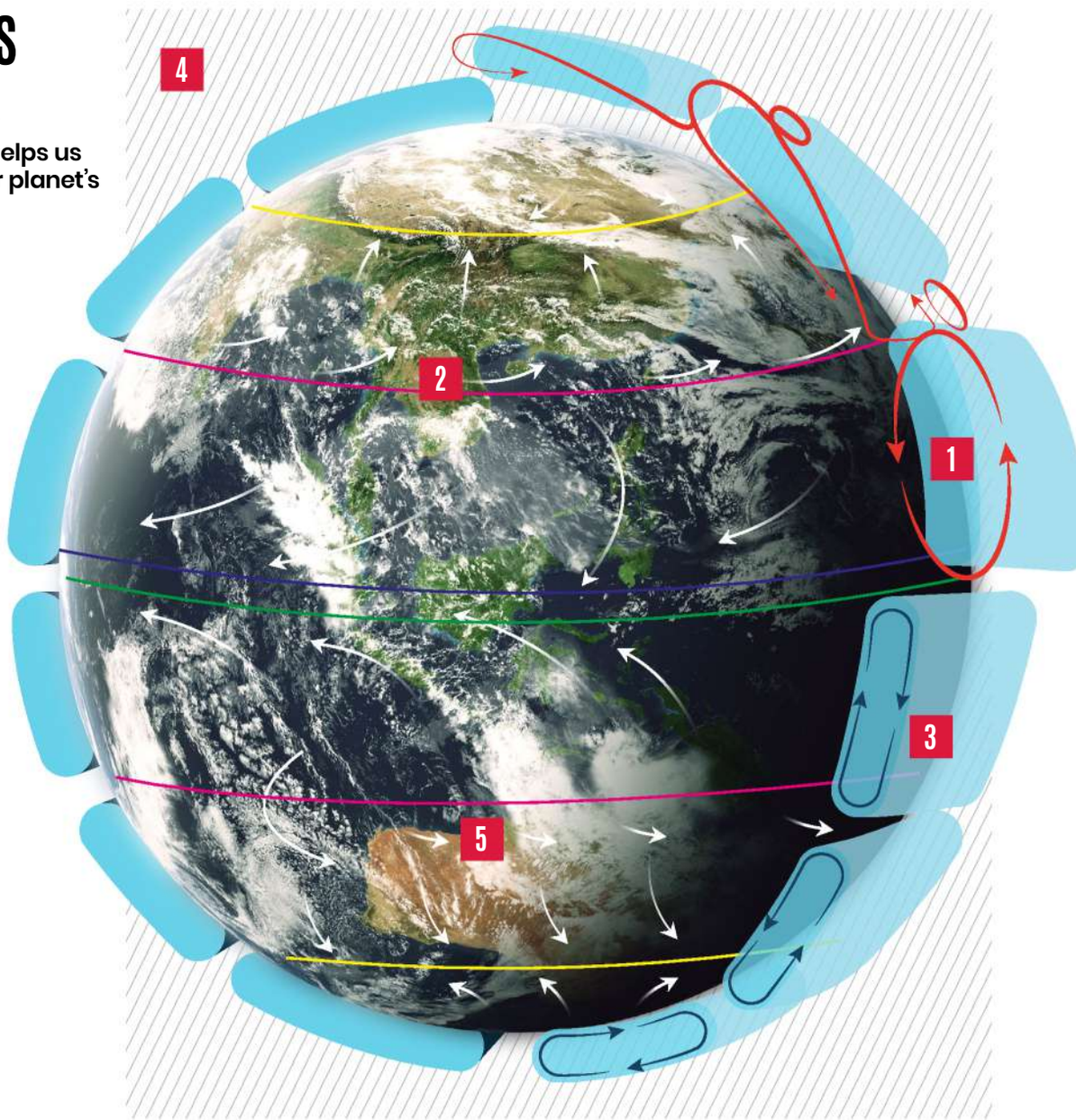
Chaos theory attempts to explain underlying patterns in this seemingly random maelstrom of data.

4 Eyes on Earth

Many satellites in orbit have been launched to view our weather from above and on a grander scale.

5 Temperature, pressure and wind speed

Even small variations in temperature, pressure or wind speed can build up into big differences elsewhere on the planet.



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CHAOS THEORY IN REAL LIFE

It thrives across the universe, but also crops up in some everyday examples

Heart versus head

Parts of the human body may exhibit chaotic patterns. There's some evidence that arrhythmia – when your heart beats out of rhythm – may occur in a chaotic way. It's possible that our brain activity has chaotic tendencies, with some suggesting that electroencephalograms show it in action.

The natural world

Chaos is rife in the animal kingdom. Biologists studying the Canadian lynx have found that their population grows in a chaotic way. Small changes in food supplies, mating habits or the spread of diseases can become magnified into big differences in animal numbers.

Cottoning on

In 1963, Polish mathematician Benoit Mandelbrot found recurring patterns in data on cotton prices from 1900 onwards that suggest they vary in line with chaos theory. They didn't follow the famous 'bell curve' as a lot of datasets tend to.

In a jam

Traffic jams can seem to clear suddenly and without any obvious cause. Tiny changes to the flow of cars can build into sizeable jams that vanish almost as soon as they arrive.

Harder to crack

Cryptographers – those responsible for setting and deciphering codes – are big users of chaos theory. A message is scrambled and unlocked using a series of keys, and some computer-based encryption methods – including online image encryption – utilise chaos maps to construct those keys.

Up to the job

Even the labour market hasn't escaped the scrutiny of chaos theorists. The way we work, apply for jobs and move between companies could well follow chaotic patterns. Insights could lead to better decisions and a more streamlined workforce in the future.

Taking stock

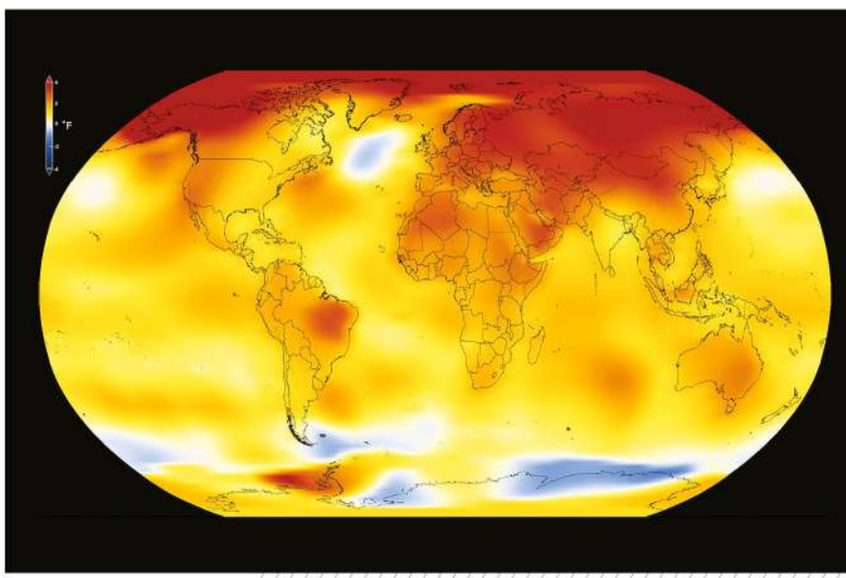
The ups and downs of the stock market are notoriously hard to predict. That's why the adage to success is 'time in the market rather than timing the market'. It may be possible that chaos theory could reveal hidden patterns in the lightning-fast trades on the world's exchanges.

Better understanding babies

The chaos in our lives starts early. Researchers have shown that they can better understand the warning signs of a condition called fetal hypoxia – where a developing fetus is starved of oxygen – if they model the situation using chaos theory.

behaviour to repeat increasingly grows to twice as long as before. Eventually, the behaviour takes so long to replicate itself that the system appears lacking in an underlying order – it looks chaotic. But there is method in the madness if you know where to look. In 1975 American mathematician Mitchell Feigenbaum discovered that the ratio of the points at which the period doubles increasingly approach the number 4.6692... as the system becomes more chaotic. This number is now known as the Feigenbaum constant in his honour.

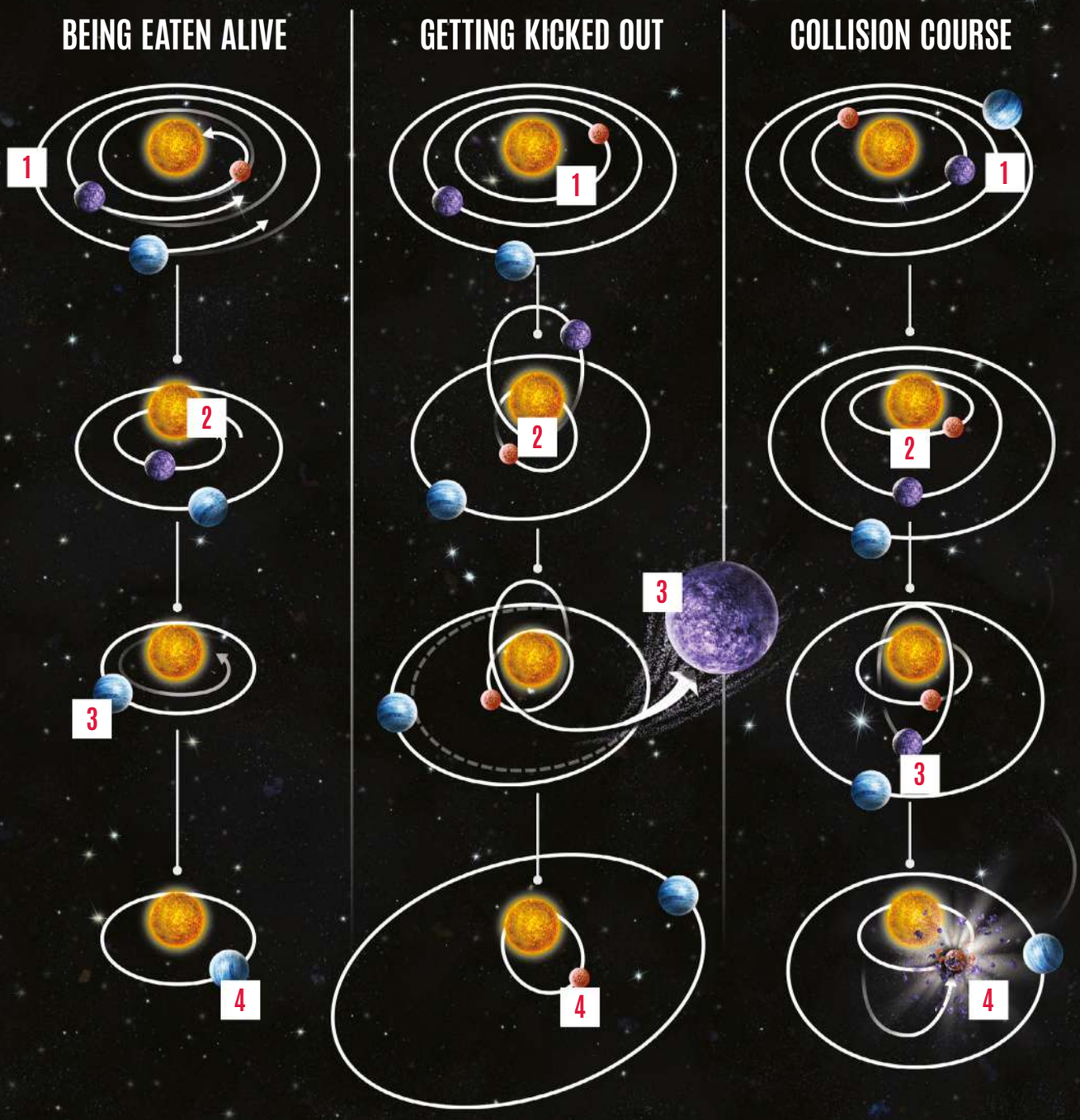
Applying chaos theory to the cosmos could help explain how Earth came to be the life-hosting planet it is today. The Sun was one of many stars formed when a vast cloud of interstellar gas and dust collapsed around 5 billion years ago. "Tiny little changes in that gas cloud can lead to very big changes in the population of stars that form," says Sutter. An extra little clump of dust here, a tiny bit of extra spin there and the Sun could have been a very different



A better understanding of chaos allows us to accurately predict the climate

HOW PLANETS DIE

Discover the many ways a world can meet its end



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BEING EATEN ALIVE

1 Tidal parade
A larger outer gas giant slows the orbits of the inner worlds.

2 A planetary conveyer belt
The orbits of the slowing inner planets lead them into the star.

3 Reducing speed
The larger outermost planet begins to slow by passing through dust in the disc.

4 Hot Jupiter
Before it can fall into the star, the dust disc dissipates and the larger planet's orbit stabilises. A hot Jupiter is born – a gas giant that sizzles at unbearably high temperatures.

GETTING KICKED OUT

1 Jumping Jupiter
This is the Jumping-Jupiter scenario. This may have ejected a planet from our Solar System long ago.

2 Meeting of worlds
Gravitational interactions between the gas giant and the extra planet cause its orbit to become elongated.

3 Catapulted out
The extra planet's orbit is so stretched out that it's thrown out of the system by an encounter with its star.

4 Moving in
The ejecting planet migrates inwards, settling into an orbit closer to the star.

COLLISION COURSE

1 In the beginning
Gravitational interactions can send smaller bodies speeding through the Solar System to crash into other things.

2 Pushing out
A resonance between a large planet and a smaller inner planet can amplify and begin to push the inner world out of its orbit.

3 Thrown into chaos
The inner planet is sent into a chaotic path – a highly elongated orbit or a trajectory that will take it out of the system.

4 Devastating impact
It's believed a huge collision like this occurred in the early Solar System.

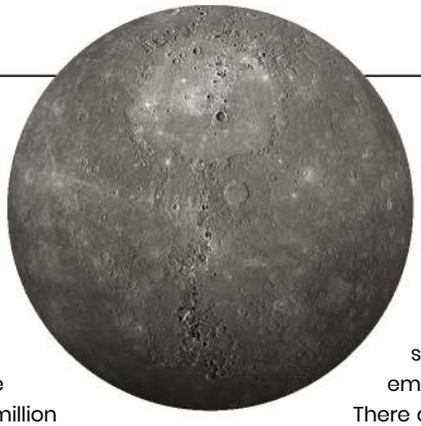
star, or even not have formed at all. Star formation may look like a chaotic system, but there could be an underlying mathematical order that reveals the likelihood of forming the kinds of stars suitable for sustaining habitable planets. In turn that could point us to the appropriate corners of the nearby universe to search for alien life. The creation of new stars is often studied by creating very complex computer simulations. "Chaos theory gives us a mathematical tool to help us get a handle on what's going on," says Sutter.

> **"It helps us to identify patterns, hidden rhythms and orders in systems that are not normally apparent"**
> **Paul Sutter**

Why is our Solar System a good place for life to emerge, evolve and thrive? Our cosmic backyard looks serene today, with planets neatly drifting around the Sun in well-behaved orbits and relatively few unstable asteroids left to careen into them. Yet today's peace and quiet belies a tumultuous youth. "We suspect a lot more planets formed around the Sun, and some of them were on chaotic orbits," says Sutter. Tiny changes in their speed and positions would have been amplified into considerable effects. Eventually they either crashed into other planets – such an event is thought to have formed the Moon – or were jacked up onto such steep orbits that they were ejected from the Solar System entirely. "Only the ones born in good places at good times get to stick around," Sutter summarises.

Working out what constitutes a good place or time is key in hunting out habitable worlds. Astronomers have spotted a whole host of weird-looking solar systems, including a planet that orbits its star in the opposite direction to its neighbours, probably because its orbit became so inclined that it flipped right over the poles of the star. This work is a shot in the arm for subscribers to the Rare Earth hypothesis – the notion that so many factors have to be just right for life that living planets like our own are few and very far between.

The butterfly effect has been popularised in Hollywood films



Yet even the chaos in our Solar System is still not complete. Over a human lifetime the path of the planets is predictable, but tiny interactions between worlds can build up to sizeable changes. Just as the weather forecast begins to break down over timescales of more than a week, we can only predict the orbits of the planets for the next 40 million years or so – an astronomical heartbeat compared to the 4.6 billion years it's been around so far. It wouldn't take much to upset the whole system, and one planet is particularly susceptible.

"There's a chance that Mercury could be ejected entirely," says Sutter. The orbit of the Solar System's smallest planet is constantly shifting. The point at which it reaches its closest approach to the Sun – its perihelion – moves by 1.5 degrees every millennium. Jupiter's perihelion is moving, too, and if the two ever get into the same rhythm, that could spell the end of Mercury. There's a one to two per cent chance its orbit will be seriously disrupted in the next few billion years. It could be ejected from the Solar System – or worse, it could smash into Earth. An inner Solar System without its first planet would itself become unstable. That could lead to Mars and Earth being nudged into a calamitous collision. It shows just how much chaos theory matters.

We already have evidence that the astronomical furniture can be significantly rearranged in rogue planets – worlds jettisoned from their home systems to wander the emptiness of space alone. There could be one Jupiter-sized orphan for every four stars in a galaxy like our Milky Way. Five per cent of Earth-sized planets would be able to cling on to any moons as they exited their system. Ejected planets form a big part of our best model of the formation of our Solar System. Astronomers running computer simulations discovered that you end up with a solar system that looks more like

"Chaos theory gives us a mathematical tool to help us get a handle on what's going on"

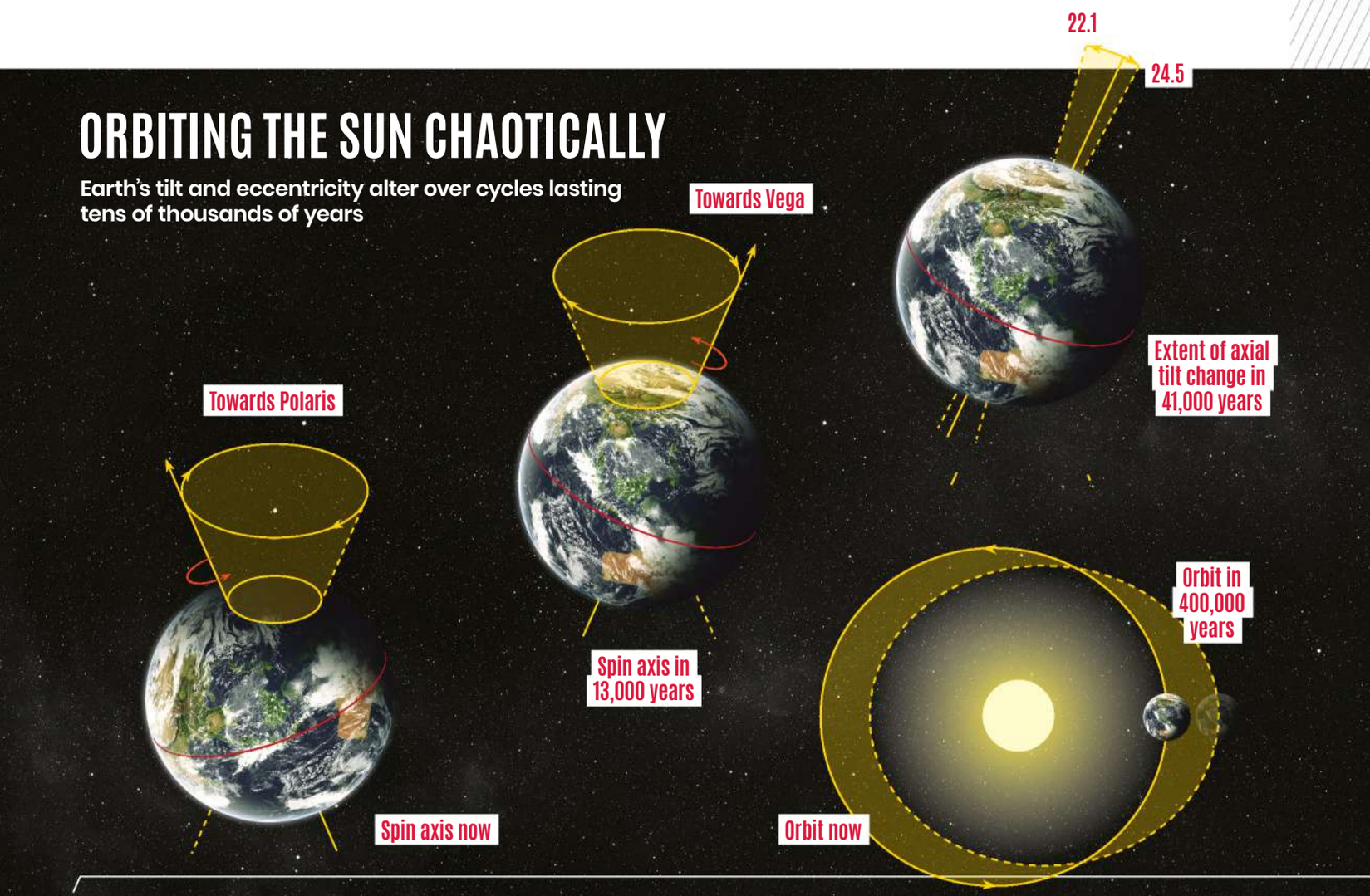
Paul Sutter

As the smallest planet, Mercury is most susceptible to the effects of chaotic changes

Varying concentrations of gas and dust give rise to very different stars

ORBITING THE SUN CHAOTICALLY

Earth's tilt and eccentricity alter over cycles lasting tens of thousands of years



ours if you start with five giant planets instead of four. Except we don't have a fifth giant planet now. Either it went rogue or it's still languishing in the backwaters of the Solar System. Astronomers increasingly suspect there is a ninth planet marooned far beyond Neptune. This 'Planet Nine' could well be a failed rogue planet that was unable to exit the Sun's gravitational clutches entirely.

Even if the chaotic Solar System doesn't set us on a collision course with our neighbours, it could still have telling consequences for our climate. In 2017, researchers studying layers of rock in the Niobrara Formation in North America found a key piece of evidence that Earth and Mars interacted in an unusual way nearly 90 million years ago. At the time there was a sea running through the middle of North America, and sediments falling to the seafloor were compressed into the rock seen there today. A team led by Professor Stephen Meyers of the University of Wisconsin-Madison found a difference in the clay levels between the layers of rock laid down over millions of years. A warmer, wetter climate leads to more clay being flushed into the sea from rivers than when the weather is drier. Alternating layers indicating wet and then dry climates were stacked up in a such a repetitive fashion that Meyer concluded there must be some cyclical phenomenon driving the changes. He points the finger at Mars and its ability to change the eccentricity

The hypothetical Planet Nine could be a failed rogue world

WHY IS CHAOS THEORY IMPORTANT?

Solving it could help us unlock the secrets of the universe

What is chaos theory?

Chaos theory is a branch of mathematics that deals with patterns that repeat in complex systems. Small changes in the system can often grow to make a big difference later down the line.

Can it predict the future?

Not quite. With some systems – like a single planet orbiting a star – it's very easy to work out where the planet will be at any given time in the future. Yet as soon as you add a third object, that reliable behaviour becomes unstable and much harder to predict. Chaos theory is all about looking for hidden patterns to get a better handle on future behaviour.

Did chaos theory appear in *Jurassic Park*?

Jeff Goldblum's character Ian Malcolm is obsessed with chaos theory and predicts that it will be the downfall of the dinosaur park. In one scene in the jeep he uses droplets of water to explain the theory.

Could understanding chaos help us with future technology?

It may be instrumental in effective quantum computers, which work by trapping and manipulating atoms using lasers. Those atoms move around chaotically, and understanding how that happens is important in being able to keep the atoms where they're needed.

Could artificial intelligence help us?

Quite possibly. Scientists trained a type of artificial intelligence called a neural network on nearly 10,000 versions of the 'three-body problem'. It learned how to solve some of the test cases more effectively than a brute-force approach.

© NASA, ESA; Caltech; Universal Pictures

The Moon formed when a chaotically disrupted planet smashed into Earth

of Earth's orbit. Eccentricity is a measure of how much a planet's orbit deviates from a circle. Any changes to this key value would change how much warmth Earth receives from the Sun and provoke the knock-on climatic effects that come with that. It would also make our seasons unequal, as Earth would spend more of the year in one part of its orbit than another.

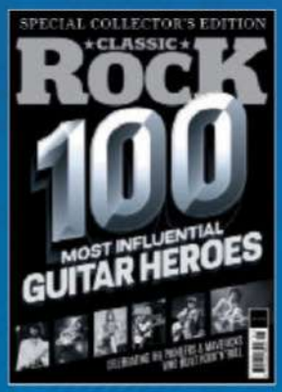
Earth can be affected in other ways, too. The tilt of our axis can vary under the gravitational influence of the other planets. Right now we lean at 23.4 degrees from vertical, but that varies between 22.1 degrees and 24.5 degrees over a 41,000-year cycle. This also changes the amount of sunlight we receive, particularly in summer and winter when we are leaning towards and away from the Sun. If small changes build up in a chaotic way, this cycle may get out of rhythm. Equally, Earth's axis moves around as our planet is wrenched by the Sun and Moon, tracing out a circle every 26,000 years or so. In the 1920s, Serbian scientist Milutin Milanković combined all these effects and their regular effect on Earth's climate, suggesting we go through periodic changes called Milankovitch cycles. They too may be susceptible to chaos.

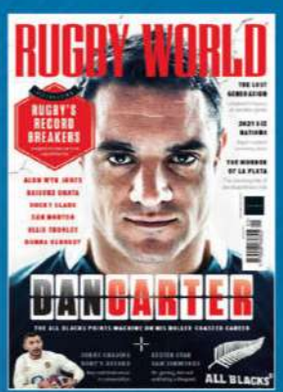
> **"We suspect a lot more planets formed around the Sun, and some of them were on chaotic orbits"**
>
> **Paul Sutter**

As we move into a future where human-made climate change is going to bite harder and harder, it's never been more important to understand the full range of factors that can influence the way our atmosphere receives, stores and transports energy. A better understanding of chaos theory goes hand in hand with more accurate climate models and a better picture of how tiny changes in the layout of the Solar System can translate into big effects on our already-warming planet.

Colin Stuart
Science author and speaker
Colin holds a degree in astrophysics, has written over 17 books on space and has an asteroid named in his honour: 15347 Colinstuart.

© Tobias Roetsch





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FUTURE TECH

FLEET LANDERS

The revolutionary landing technology that could slash the cost of landing probes on rocky planets

One of the major problems of planetary exploration is landing a probe safely on another planet. Landers and rovers need to touch down in a very particular, usually flat area. The fact that the team only ever gets one attempt at it makes the process an extremely risky event, with disastrous and expensive repercussions following any kind of mistake during the nail-biting process.

Fleet landers, proposed by the Jet Propulsion Laboratory team at NASA, could make this moment of tension a thing of the past. The idea is to attach dozens of sheets to a parachute lander, which releases them above a planet or moon. These sheets then flutter down and spread over the surface. Because they're flat and flexible, they'll settle anywhere. They also don't need to be carefully landed using expensive rockets – because dozens will land at a time, there's a higher chance of a successful landing.

The plan is for the one-metre (3.3-foot) squared and one-centimetre (0.4-inch) thick landers to piggyback on spacecraft and be dropped on inhospitable bodies such as Mars, Europa, Enceladus and Titan. Rovers already have problems on the erratic surface of Mars, so would struggle in the extreme environment of Venus, while the geysers of Europa would also pose a risk to traditional ventures. But none of these would be a problem for a fleet of thin, flat surface landers, because if a few get lost or swallowed up, there are plenty of others that can carry on their work.

1 Parachute dropper
Landers can be deposited on the planet or moon using parachutes, much less expensive than the rocket landers used by traditional rovers.

2 Stacked high
Dozens of fleet landers can be stacked onto each parachute, enabling for a large area to be covered as the landers get distributed piece by piece.

3 Where to go?
Mars is one option, although the moons Europa and Enceladus are also targets – they have never been explored due to their inaccessibility for traditional landers.

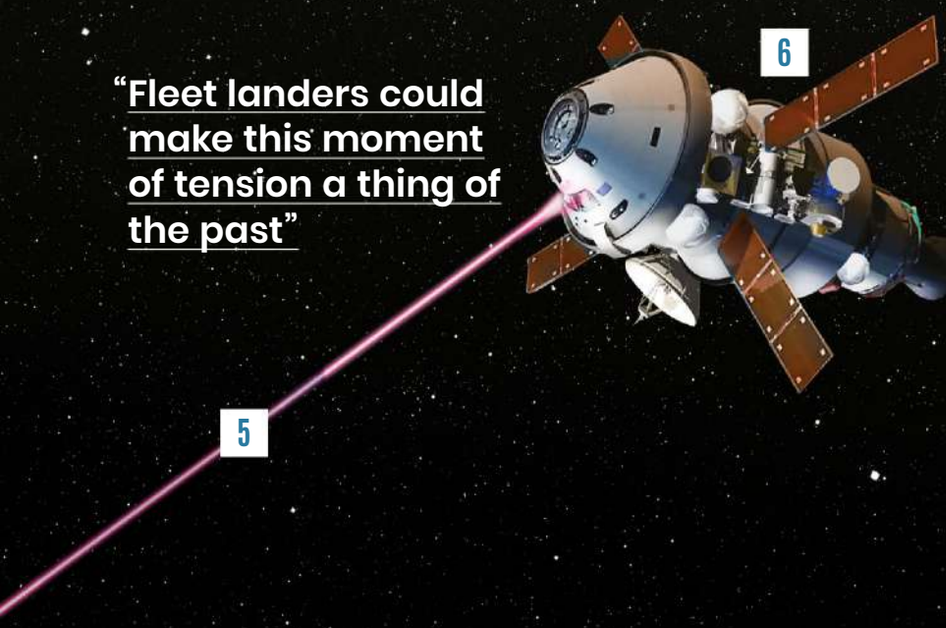
They will be able to conduct experiments such as locating water, measuring pH levels, analysing dust particles and taking photographs. They will use super-thin instruments implanted into the sheets, such as wide-angle cameras, wireless transmitters and temperature, altitude and pressure sensors. They will gain power from solar cells implanted into the sheets, thin batteries that store energy and radio-isotope heater units, which provide energy via the heat created by the decay of plutonium-238. They could also be energised using a beam from the craft that dropped them on certain worlds – some are too far from the Sun to provide energy.

Actuators will be set into the sheets, lifting them up so they can either be blown along by Martian winds or roll themselves into balls and negotiate the planet on tiny, retractable feet. This enables them to cover vast distances of the surface and map huge areas with wide-angle cameras. Enceladus will be a fascinating body to explore up close due to the liquid oceans found underneath its surface. In-situ wide-angle photographs could unlock many of the secrets hidden from conventional orbiters.

Although rovers, orbiters and conventional landers will still play a vital role in space exploration, these fleet landers are an attractive proposition for research teams looking to create a low-cost, low-risk venture to distant worlds. They can perform many tasks required of bigger and more expensive equipment and don't require the precision when landing.

V 2D landers would have the advantage of lower risk, more mobility and easier landing than the Mars rovers

"Fleet landers could make this moment of tension a thing of the past"



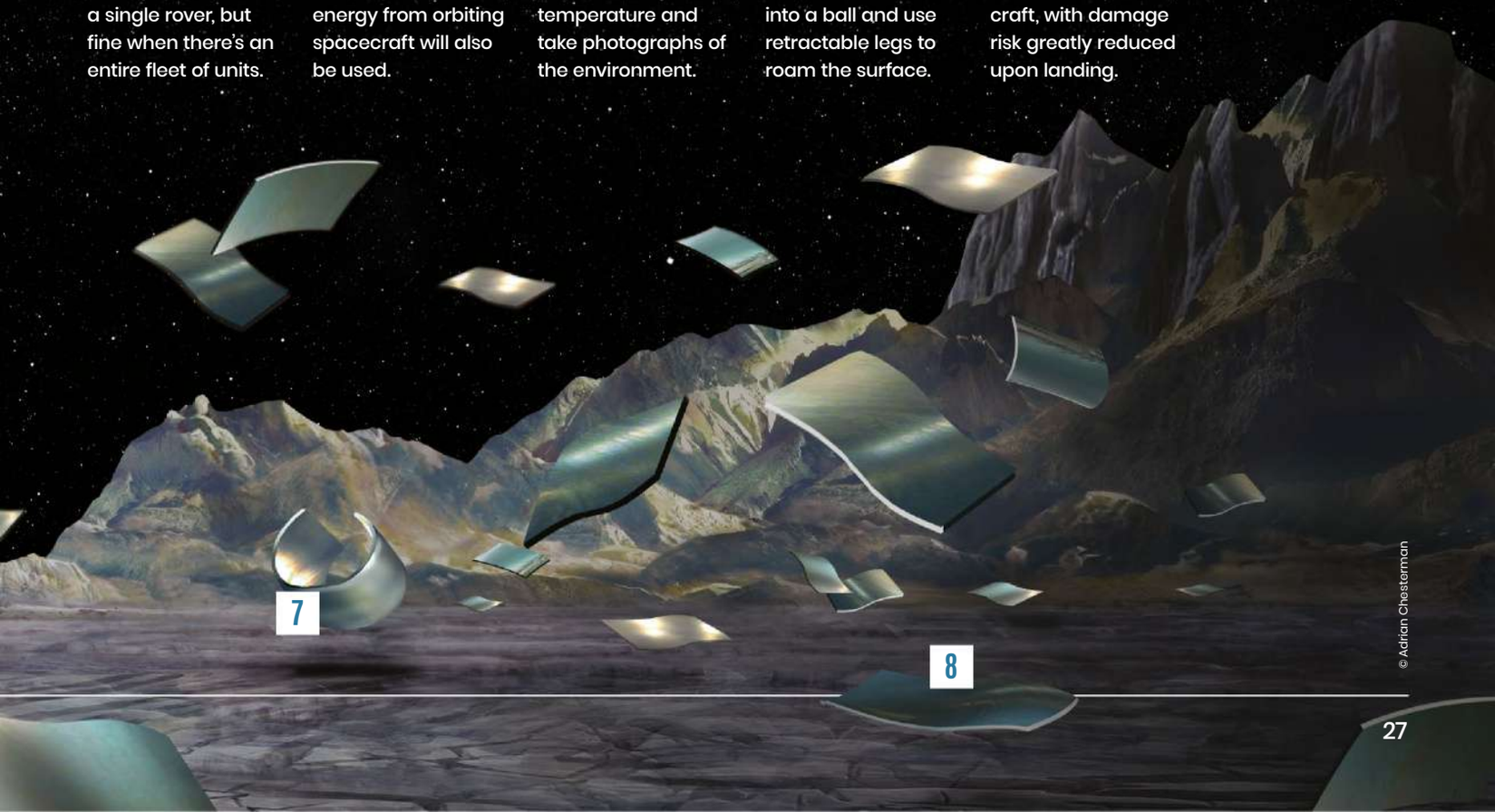
4 Disposable
Because many landers can be dropped, a number will be lost. This is unacceptable when we're talking about a single rover, but fine when there's an entire fleet of units.

5 Power
Solar cells and batteries will provide power to the landers, although radio-isotope heater units and beamed energy from orbiting spacecraft will also be used.

6 Science studies
The landers will be able to perform in-situ examinations of planetary composition, measure temperature and take photographs of the environment.

7 Movement
Actuators can be built into the landers to enable them to get caught up by Martian winds, or they can roll up into a ball and use retractable legs to roam the surface.

8 Material
The material will be both lightweight and flexible, enabling many landers to be carried by a single craft, with damage risk greatly reduced upon landing.



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BIO+

André Kuipers

Born 5 October 1958, Kuipers is a Dutch physician and ESA astronaut who has flown into space twice. His first mission in April 2004 was a short-duration stay on the International Space Station (ISS) for a week and a half. His second mission launched on 21 December 2011 and returned on 1 July 2012, during which time he was responsible for berthing SpaceX's Dragon, the first private vehicle to dock with the ISS.

André Kuipers

"Everybody in the space world was watching"

The only Dutch astronaut to fly into space twice, Kuipers also berthed a private spacecraft with the ISS for the first time

Interviewed by Jonathan O'Callaghan

Why did you decide to become an astronaut?
It all started when I was about 12 with some science-fiction books I had from my grandmother. That triggered my fantasy, but it was still a boy's dream. I grew up in the period that we landed on the Moon and launched Skylab, and then the Space Shuttle was built, so I saw all these beautiful pictures. And then the ESA was founded, and it had a Dutch astronaut. I thought 'hey, wait a minute, maybe it's not just a boy's dream adventure'. I saw a picture of John Young in the Space Shuttle with glasses, and I had been wearing glasses since I was 12, so I began to realise that these were normal people and not just test pilots.

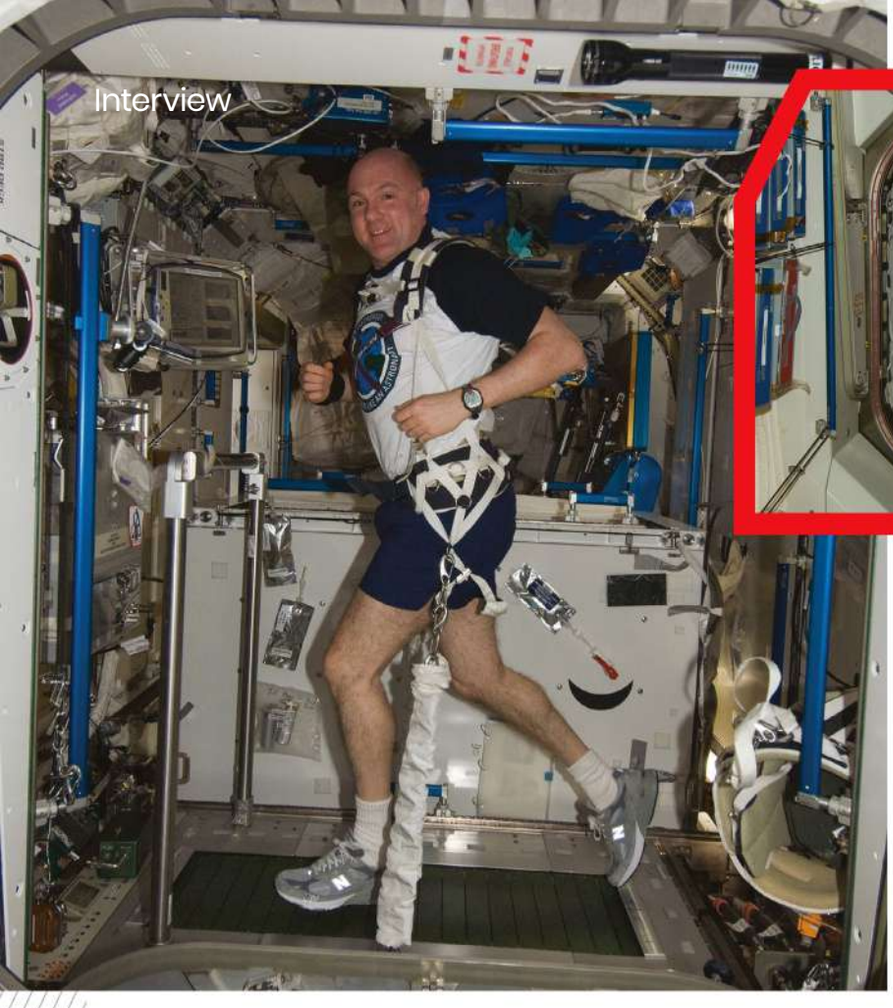
What sort of training did you do for your first mission?
Because the ESA needed to select astronauts from smaller countries like Holland, there was initially no direct flight for us. I began training all by myself, and I did some basic training in Star City. I was studying orbital mechanics, planetary science and some other basic stuff until Holland decided to sponsor my flight, and then I started training for the DELTA mission [on Soyuz TMA-4 in April 2004].

How did it feel to be selected for a mission?
I'd been looking forward to it for many years. You hope that nothing goes wrong, because the biggest worry for astronauts is not the launch but that somebody cancels the flight or you get disqualified. I was very pleased when I was walking to the rocket. I thought 'this is it; it's going to happen.' It was very exciting. You feel it in your stomach as if you're sitting in a roller coaster. You're in your seat belt and there's no way back!

What was that first launch like?
You sort of know what's coming from training, but not completely. You've been in a centrifuge, you did the launch sequence

© NASA

The Dragon spacecraft was caught by Kuipers and berthed with the ISS for the first time on 25 May 2012



Kuipers tethered down while exercising in microgravity

Kuipers pictured with free-floating fruit near the Unity node on the ISS

so many times – and all the things that could go wrong – and you know the sound of the commands, so everything comes together. The actual launch was much more relaxed than the simulation because in the simulator they design it so that everything goes wrong. There's always something failing – you lose thrust or you don't disconnect from the third stage, problems to solve like that. In reality everything is clean and quiet, so you concentrate on the screen and see if anything is wrong but everything is okay, so it's even more relaxing.

What was your role on that mission?
I'm a medical doctor, and when I wanted to become an astronaut I knew that medical doctors had been to space. I expected that I would become a mission specialist, probably on the Space Shuttle. But then they told me I was going to Russia to fly on the two-person Soyuz and I would be flying in the left seat [the pilot's seat]. That was very surprising because normally the foreign astronauts would fly in the right seat where you don't do much and you have a lot less tasks. Normally the ones who flew in the left seat were test pilots. I was the first non-pilot and non-engineer to fly my first flight in the left seat.

"Launch was much more relaxed than the simulation because in the simulator they design it so that everything goes wrong"

Was it hard to pilot the Soyuz?
It was quite a challenge, but very interesting. The hardest part was that everything is in Russian and abbreviated, so having to learn abbreviated technical Russian was quite a challenge.

How long was that mission?
It was a short-duration mission. It was 11 days, of which nine were in the International Space Station. I brought one crew member up, because this was in the time that we could have only two people on board the Soyuz because of the Space Shuttle Columbia disaster, and we couldn't get enough resources and consumables to the station for a larger crew, so there were only two permanent crew members on the station. Then I flew back with another crew member on the previous Soyuz spacecraft that was already docked with the station. It was great and so interesting. I thought 'wow, I don't want to go back. I want to be here for a longer time.' Then I knew that I would try and fly again.

When you were selected for the long-duration Expedition 30/31 mission, was your training the same?
This was totally different. It was a new Soyuz spacecraft, so I had to do a lot of new training with new software and other flight-control systems. Also, on the DELTA mission, I only had to do some experiments on the ISS. I knew how to make food and use the toilet in the Russian segments, and in the American lab I knew how to do my experiments. But now we had a totally different situation because I was assigned to fly as a flight engineer for the ISS, and the ISS was now twice as big, so I had to know all the systems on board. The Japanese module, the Columbus module, the Cupola module – all these things were new. I had to learn how to be an operator and a specialist in these areas. I became a specialist for Columbus, the Japanese module, the robotic arm, spacewalks and the Automated Transfer Vehicle (ATV), and I became an operator on the US segment. I was a specialist for the Dragon capsule capture and berthing.

You were tasked with bringing the first Dragon to the ISS. What was that like?
Yes, together with Don Pettit. Several crews were trained for the event, but things were postponed, so finally it

came down to us. Because this was the first Dragon we didn't know if it would behave properly, so my task was to send it back and forth together with the ground. I also gave commands for Dragon to switch its lights on and off to see if the signals were going through properly and that it was flying to our wishes.

Did anything go wrong?
There was one moment where we saw Dragon retreating and I thought 'oh, we didn't give that command... what's going on?' But it turned out that the ground did that because it was having problems with its rangefinder. For a moment we thought it wasn't going to work, but then they said it was okay to approach again.

How did the capture go?
I was controlling the Dragon and checking all the distances, making sure that it was in a free drift. You don't want either the station or the Dragon to move around when you're trying to grab it with the arm, so it has to go in free drift so it doesn't move. I gave Don the go-ahead and he grappled it, then I took over and turned the Dragon around. It was interesting with this arm because you have three ways to move with the angles of the joints. I got to use all three of them, which was nice because you train for that for many years, so it's nice to get to use all the possibilities of this arm. And then we berthed it with the ISS, which isn't the same as a docking like the ATV or Soyuz. A berthing is where you pull it in yourself. This was a great moment, an operational highlight, and maybe even the highlight of my career, because this is why you train all this time. I mean you really have this spaceship in your hands, and it's the very first one, and then you click it and connect it with the station. It was a great moment.

What was the feeling on board the station at the time?
We felt excited. Everybody in the space world was watching us because this was the start of the commercialisation of human spaceflight. We had that already with rockets and satellites, but for human spaceflight we hadn't seen commercialisation yet, and this was the first one. I realised it was the start of a new era, with government agencies hiring SpaceX or Orbital Sciences or whatever to bring goods and even future astronauts to the space station. Then the agencies can continue with exploration, and this is the way it should be. This is how I expect things will develop, that NASA, the ESA and others will altogether go back to the Moon, then asteroids and Mars, leaving low-Earth orbit to more commercial activities like industry and tourism.

Would you like to go to space again?
I would love to fly again. It's not very likely that I will fly again for the ESA, but you never know what kind of developments are coming.

Kuipers poses with crewmates from the Expedition 30/31 team

FOCUS ON

DYING RED GIANT SEEN BLOWING SMOKE RINGS

Two telescopes charted the structure of a star about to die in unprecedented detail

Reported by Elizabeth Howell

A red giant star in the final stages of its existence has been caught emitting strange smoke-like rings for the first time. The star, called V Hydrae, located some 1,300 light years from Earth, is a so-called asymptotic giant branch (AGB) star – a star which has reached the final stage of its red giant phase of existence before collapsing into a white dwarf. Observing the behaviour of such stars helps astronomers understand what happens in the final stages of the stellar death process.

Astronomers have known before that stars in this phase dredge up material from their cores and expel it into the surrounding space. It was this expulsion of material that a team of scientists from NASA's Jet Propulsion Laboratory (JPL) and the University of California, Los Angeles (UCLA), observed when they looked at V Hydrae using the Atacama Large Millimeter/submillimeter Array (ALMA) and the Hubble Space Telescope. They discovered that the star is shedding six discs and two hourglass-shaped structures of matter from its interior, which is at this stage known to fuse helium into carbon. Stars during the regular phase of their lives fuse hydrogen into helium. The moment when hydrogen runs out marks the beginning of the red giant phase, which eventually sees the star burning helium and producing carbon. In the AGB phase, stars are gradually running through their helium reserves as well, and that's what seems to be happening to V Hydrae.

"Our study dramatically confirms that the traditional model of how AGB stars die – through the mass ejection of fuel via a slow, relatively steady spherical wind over 100,000 years or more – is at best incomplete, or at worst incorrect," said lead scientist Raghvendra Sahai, an astronomer at JPL. Astronomers were particularly surprised that V Hydrae was blowing out 'smoke rings' of dust instead of just gaseous atmosphere, added astronomer Mark Morris of UCLA.

This finding has high relevance given that more than 90 per cent of stars with a mass equal to the Sun or larger eventually become AGBs as they lose the ability to generate energy through nuclear fusion. "The end state of stellar evolution – when stars undergo the transition from being red giants to ending up as white dwarf stellar remnants – is a complex process that's not well understood," added Morris. "The discovery that this process can involve ejections of rings of gas simultaneous with the production of high-speed, intermittent jets of material brings a new and fascinating wrinkle to our exploration of how stars die."

The two hourglass-like clouds and an additional jet-like structure were warping away from the star at 240 kilometres (149 miles) per second. The hourglass-like clouds are not quite new to science, as astronomers spotted such phenomena before in stars shedding atmospheres, like within the Southern Crab Nebula.

V Hydrae has been known to emit bursts of superheated gas, or plasma, around every 8.5 years, and scientists believe that some of its strange behaviour might have something to do with a companion star, the existence of which has not been confirmed. "Each time we observe V Hydrae with new observational capabilities, it becomes more and more like a circus, characterised by an even bigger variety of impressive feats," Sahai said. "V Hydrae has impressed us with its multiple rings and acts, and because our own Sun may one day experience a similar fate, it has us at rapt attention."

> "Our study dramatically confirms that the traditional model of how AGB stars die is at best incomplete, or at worst incorrect" **Raghvendra Sahai**

ALL ABOUT ALMA

A very large collection

ALMA is made up of 66 dishes, all up to 12 metres (39 feet) across and weighing in at 100 tonnes each. The dishes that comprise ALMA gather faint radio waves from space.

Going digital

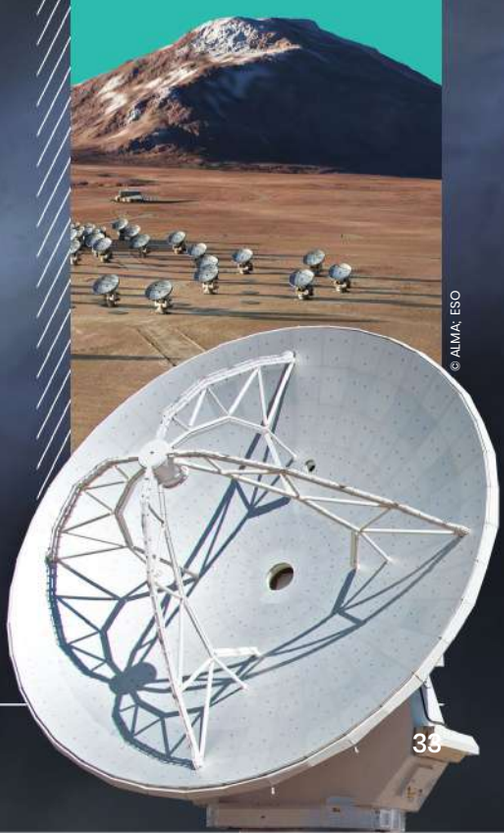
ALMA's dishes are able to turn the incoming signals from analogue into digital by converting the radio waves into binary computer code.

Supercomputer power

The digital data is sent along 15 kilometres (9.3 miles) of optical fibres to a supercomputer whose power matches that of 3 million laptops.

Dished out

When astronomers around the world get the data, they're able to turn it into images that are ten times sharper than those taken by Hubble.



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MOON PROFILE

TITAN

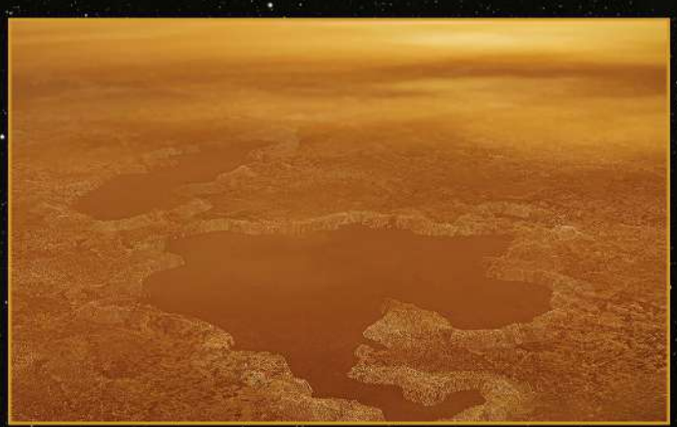
Saturn's biggest moon is a harsh, uninhabitable world, yet has uncanny similarities to our home planet

Titan is one of the most intriguing moons in our Solar System. From the outside astronomers see a ball of golden-orange haze, but what's hiding beneath this atmosphere is what intrigues them – a freezing world with bodies of liquid. Planetary scientists are fascinated by Titan and its unusual contents. Titan, the largest moon of Saturn and second-largest moon in the Solar System behind Jupiter's Ganymede, is an icy ball that stretches out to almost 5,150 kilometres (3,200 miles) in diameter, nearly 50 per cent wider than Earth's Moon. Due to Saturn's position in space, around 1.4 billion kilometres (870 million miles) from the Sun – nine times farther than Earth's average distance – its satellite Titan receives sunlight that is 100 times fainter than the light on Earth. This freezing world may be one that is inhospitable for humans, but its icy lakes are a close Earth analogue. These features have been the subject of many studies.

Though there are many interesting moons in the Solar System, Titan is the most Earth-like: it has an atmosphere and is rocky, but also has bodies of liquid on the surface with a rain cycle replenishing them. All of this happens on a moon that has a surface temperature of -179 degrees Celsius (-290 degrees Fahrenheit). Unlike Earth, there aren't lakes of water on Titan, as that would have been frozen. Instead the lakes, rivers and seas are filled with liquid hydrocarbons such as methane and ethane. These complex molecules are capable of existing as liquids at such a cold temperature.

Titan has an atmospheric pressure 60 per cent greater than that of Earth. This would feel the same as swimming 15 metres (50 feet) below the surface of Earth's oceans. This atmosphere is comprised mostly of nitrogen, at a whopping 95 per cent. Around five per cent is methane and the extremely small remainder is carbon-rich compounds, creating the orange haze that is seen from afar. The presence of an atmosphere and surface liquid means there must be a cycle of evaporation and condensation, creating clouds of methane ice and cyanide gas and precipitation in the form of methane rain. A moon with a weather cycle is unusual, and astronomers are amazed at how Earth's water cycle can be applied to a distant, alien world.

But there's a mystery about Titan that astronomers can't seem to explain with any conviction, and that's what is replenishing Titan's atmosphere. It's known that sunlight breaks up methane at the top of the moon's atmosphere, but scientists are still wondering what is bringing more methane into the atmosphere in its place. One suggestion has been volcanic activity. The presence of volcanoes would be yet another amazing similarity between Titan and our home planet if they're found by a future mission.



Huygens sent back images of the Titanian surface to Cassini

"Titan has bodies of liquid on the surface with a rain cycle replenishing them"

Titan's thick atmosphere makes the planet appear hazy from afar

Atmospheric composition

95%
NITROGEN

5%
METHANE

+

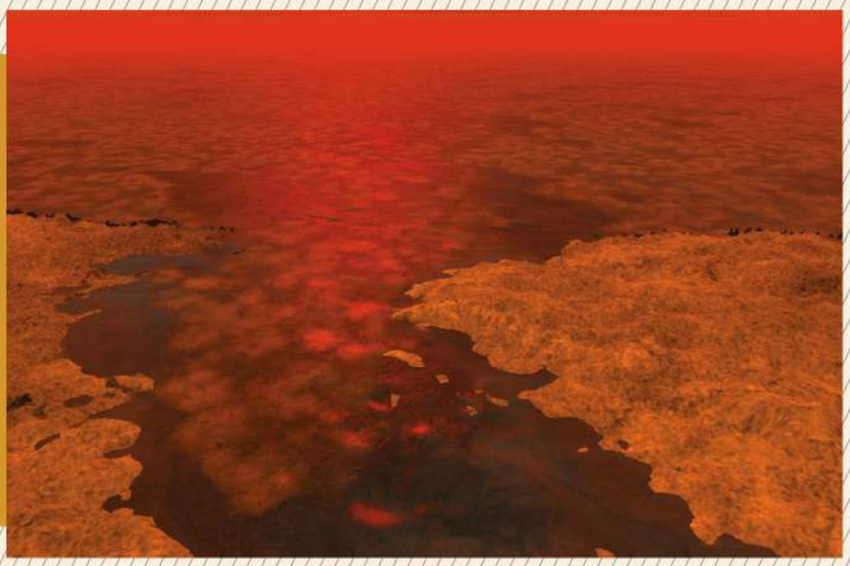
TRACES OF CARBON-RICH COMPOUNDS

© Getty: NASA/JPL-Caltech; NASA

NEWS FROM TITAN

Understanding the atmosphere

Titan's atmosphere is an enigma. Ever since its discovery, astronomers have been trying to explain how such a dense atmosphere and surface liquid arose and were preserved for millions of years. "Because Titan is the only moon in our Solar System with a substantial atmosphere, scientists have wondered for a long time what its source was," says Kelly Miller, a research scientist at the Southwest Research Institute in San Antonio, Texas. "The main theory has been that ammonia ice from comets was converted into nitrogen to form Titan's atmosphere. While that may still be an important process, it neglects the effects of a very substantial portion of comets: complex organic material."

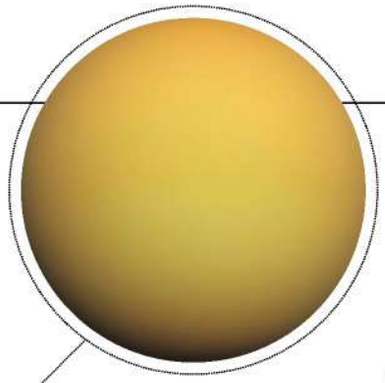


Changing seasons

Much like seeing the seasons change from summer to winter on Earth, scientists have spotted signs of changing seasons on Titan using valuable data from NASA's Cassini spacecraft. Using pictures of the moon's northern hemisphere, Rajani Dhingra of NASA's Jet Propulsion Laboratory and her team have seen rainfall at the north pole. The rainfall also provides the first indication of the beginning of a summer season, courtesy of Cassini and its Visual and Infrared Mapping Spectrometer instrument. The spacecraft's near-infrared capabilities allowed it to peer inside the atmosphere and observe this rainfall. Compared to Earth's yearly cycle of four seasons, a season on Titan lasts seven Earth years.

Dust storms sweeping the surface

Cassini spotted giant dust storms sweeping across Titan's surface, with astronomers trying to work out what is generating these powerful gusts around the equatorial region. In the same way the weather changes with the seasons on Earth, a similar phenomenon occurs on Titan. In this case, when the Sun crosses Titan's equator, massive clouds are formed in these tropical regions, creating powerful methane storms. After more modelling scientists discovered that these are actually clouds of organic molecules raised from the dune – the first observation of a dust storm on Titan.



HUYGENS' DESCENT TO TITAN

- **Time:** 14 January 2005 10:13 UTC
  Activity: Huygens reached the top of Titan's atmosphere.
- **Time:** 10:17 UTC
  Activity: The pilot parachute deployed; a minute later the front shield was released and transmission to Cassini began.
- **Time:** 10:32 UTC
  Activity: The main parachute separated and the drogue parachute was deployed to guide Huygens to the right spot.
- **Time:** 11:57 UTC
  Activity: Huygens made a successful touchdown on Titan.
- **Time:** 14:44 UTC
  Activity: Cassini stopped collecting Huygens data, thus concluding its work. At 15:14 UTC the first data was sent to Earth.

All times above are the Earth-received time – around 67 minutes after the event happened at the spacecraft

Titan orbits in 15 days and 22 hours

TITAN TIDBITS

2%
Jupiter's Ganymede is only two per cent larger, meaning there isn't much size between the two largest moons in the Solar System

Data suggests the presence of a liquid ocean beneath Titan's surface

Huygens holds the record for the most distant landing of a human-made probe

The 'sand' on Titan's dunes is composed of dark coffee-like hydrocarbon grains

Titan is tidally locked to Saturn, meaning only one side of Titan is facing Saturn at all times

600KM
Titan's atmosphere extends about 600 kilometres (370 miles) above its surface

MISSIONS TO TITAN

Titan isn't exactly nearby. When Earth and Saturn are closest to each other they are still 1.2 billion kilometres (746 million miles) apart. This means visits to Titan in the past have been few and far between. The first probe to visit the Saturnian system was NASA's Pioneer 11 in 1979, followed by Voyager 1 and 2 in 1980 and 1981 respectively. NASA's Voyager spacecraft were pivotal in making initial measurements of its physical properties, such as mass, density, composition and so on. These observations caught the attention of many researchers because of their irregularity.

The best spy sent to the Saturnian system – and in particular Titan – was the Cassini spacecraft and its accompanying Huygens lander. Cassini-Huygens arrived at Saturn in July 2004 and made many observations of the moon before Huygens was released with the intention to burst through the hazy atmosphere of Titan and land on its surface. On 14 January 2005, Huygens made its successful descent onto Titan before its batteries died and communication with Cassini ceased. All observations of Titan after the fact were made by Cassini before it ended its mission by crashing into Saturn's atmosphere in September 2017. The data collected by Cassini is still providing new discoveries over five years after the mission's end.

There have been talks of sending more probes to the exciting moon using new and innovative technology. One such proposal is the Dragonfly lander, part of NASA's New Frontiers program. The Dragonfly lander will not just sit on the surface like Huygens, it will be a dual-quadcopter drone capable of moving around Titan's thick, nitrogen-rich atmosphere. This would allow astronomers to get a closer look at different surface features and would allow more freedom in movement than a rover.

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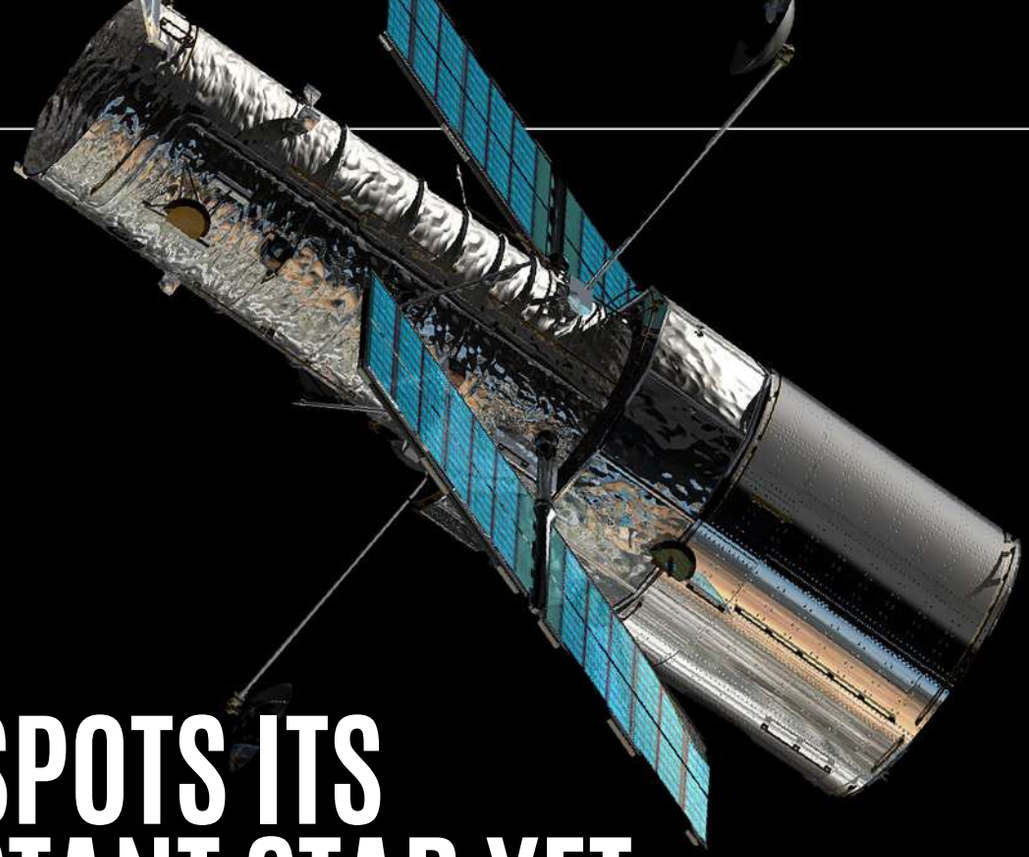


FOCUS ON

HUBBLE SPOTS ITS MOST DISTANT STAR YET

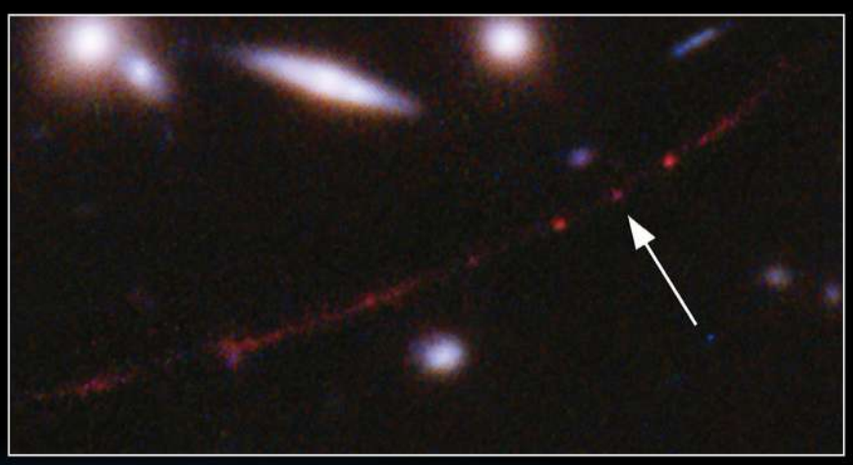
Meet Earendel, a star whose light took 12.8 billion years to reach Earth

Reported by Charles Q. Choi

The most distant single star yet dates back to less than 1 billion years after the universe's birth in the Big Bang and may shed light on the earliest stars. Scientists nicknamed the star 'Earendel', from an Old English word meaning 'morning star' or 'rising light'. Earendel, technical designation WHL0137-LS, is at least 50 times the mass of the Sun and millions of times as bright.

This newfound star is so far away that its light has taken 12.8 billion years to reach Earth, appearing to us as it was when the universe was about 900 million years old, just seven per cent of its current age. Until now, the most distant single star detected, discovered by Hubble in 2018, existed when the universe was about 4 billion years old, or 30 per cent of its current age. "This finding gives us an opportunity to study a star in detail in the early universe," said lead scientist Brian Welch, an astrophysicist at Johns Hopkins University in Baltimore.

Even a star as brilliant as Earendel would usually be impossible to see from Earth given the vast divide. Previously, the smallest objects seen at such great distances were clusters of stars embedded in early galaxies. Scientists detected Earendel with the help of a huge galaxy cluster, WHL0137-08, sitting between Earth and the star. The gravitational pull of this enormous cluster warped the fabric of space-time, resulting in a powerful natural magnifying glass that greatly amplified the light from objects behind the galaxy. This gravitational lensing has distorted the light from the galaxy hosting Earendel into a long crescent researchers named the Sunrise Arc.



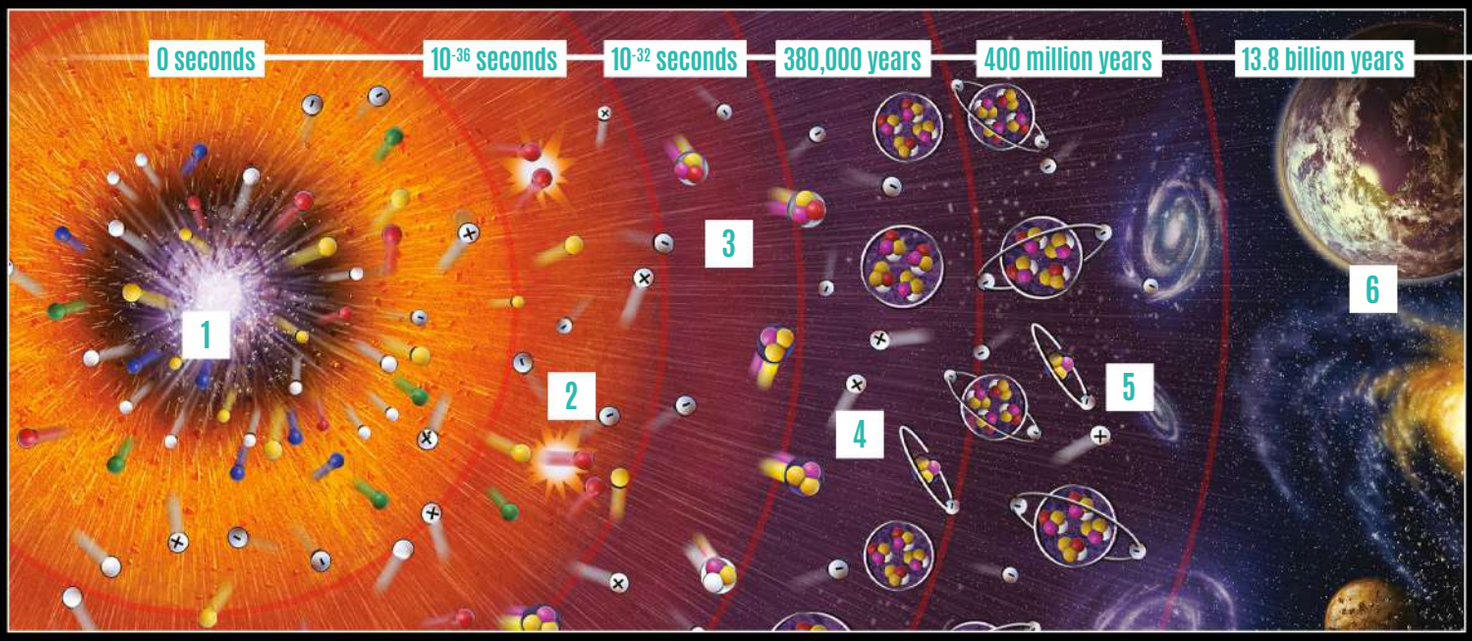
Earendel is indicated by an arrow in this image from the Hubble Space Telescope

The rare way in which Earendel aligned with WHL0137-08 meant that the star appeared directly on or extremely close to a curve in space-time that provided maximum brightening, causing Earendel to stand out from the general glow of its home galaxy. This effect is analogous to the rippled surface of a swimming pool creating patterns of bright light on the bottom of the pool on a sunny day – the ripples on the surface act as lenses and focus sunlight to maximum brightness on the pool floor. Welch emphasised that this is not the most distant object scientists have ever discovered. "Hubble has observed galaxies at greater distances," he explained. "However, we see the light from their millions of stars all blended together. This is the most distant object where we can identify light from an individual star."

He also noted this star was distant, but not old: "We see the star as it was 12.8 billion years ago, but that doesn't mean the star is 12.8 billion years old." Instead it's probably just a few million years old. "Given its mass, it almost certainly hasn't survived to today, as more massive stars tend to burn through their fuel faster and thus explode or collapse into black holes sooner," he added. "The oldest stars known would have formed at a similar time, but they are much less massive so they have continued to shine until today." Many details about Earendel remain uncertain, such as its mass, brightness, temperature and type. Scientists aren't even sure yet if Earendel is one star or two – most stars of this mass usually do have a smaller, dimmer companion, and it's possible that Earendel is outshining its partner.

Scientists intend to conduct follow-up observations with NASA's recently launched James Webb Space Telescope to analyse Earendel's infrared light and pin down many of its features. Such information could help shed light on the first stars in the universe, which formed before the universe was filled with the heavy elements produced by successive generations of massive stars. "I think one of the most exciting things about this result is that it opens a new window into the early universe," Welch said. "Typically at these distances, we see full galaxies as small, fuzzy objects and we then infer details about the stars within from their aggregate light." Not so for Earendel. "With this lensed star, we can study its light independently," he said. "This lets us compare directly to stars in the Milky Way and look for differences which will improve our understanding of stars in the early universe."

> **"This finding gives us an opportunity to study a star in detail in the early universe"**
> **Brian Welch**



1 The beginning The absolute beginning of our universe according to the Big Bang theory, which started out as a dense, hot, timeless, dimensionless singularity.

2 Cosmic inflation A rapid expansion phase after the Big Bang increased the size of the universe from that of an atom to a football. The universe was made of pure energy.

3 Cooling and quarks After inflation ended, the universe cooled enough for subatomic quarks, electrons and other particles to form from the available energy.

4 Atoms form Further expansion and cooling meant subatomic particles formed into atoms. Hydrogen, helium and lithium filled the universe, which became transparent as a result.

5 First stars and galaxies are born Hydrogen and helium gas clumps collapsed under gravity to form the first stars. They formed inside galaxies, which lie in dark matter halos.

6 Present day Several generations of star formation and destruction created and spread chemical elements throughout space. That created planets with complex chemistry and even life.

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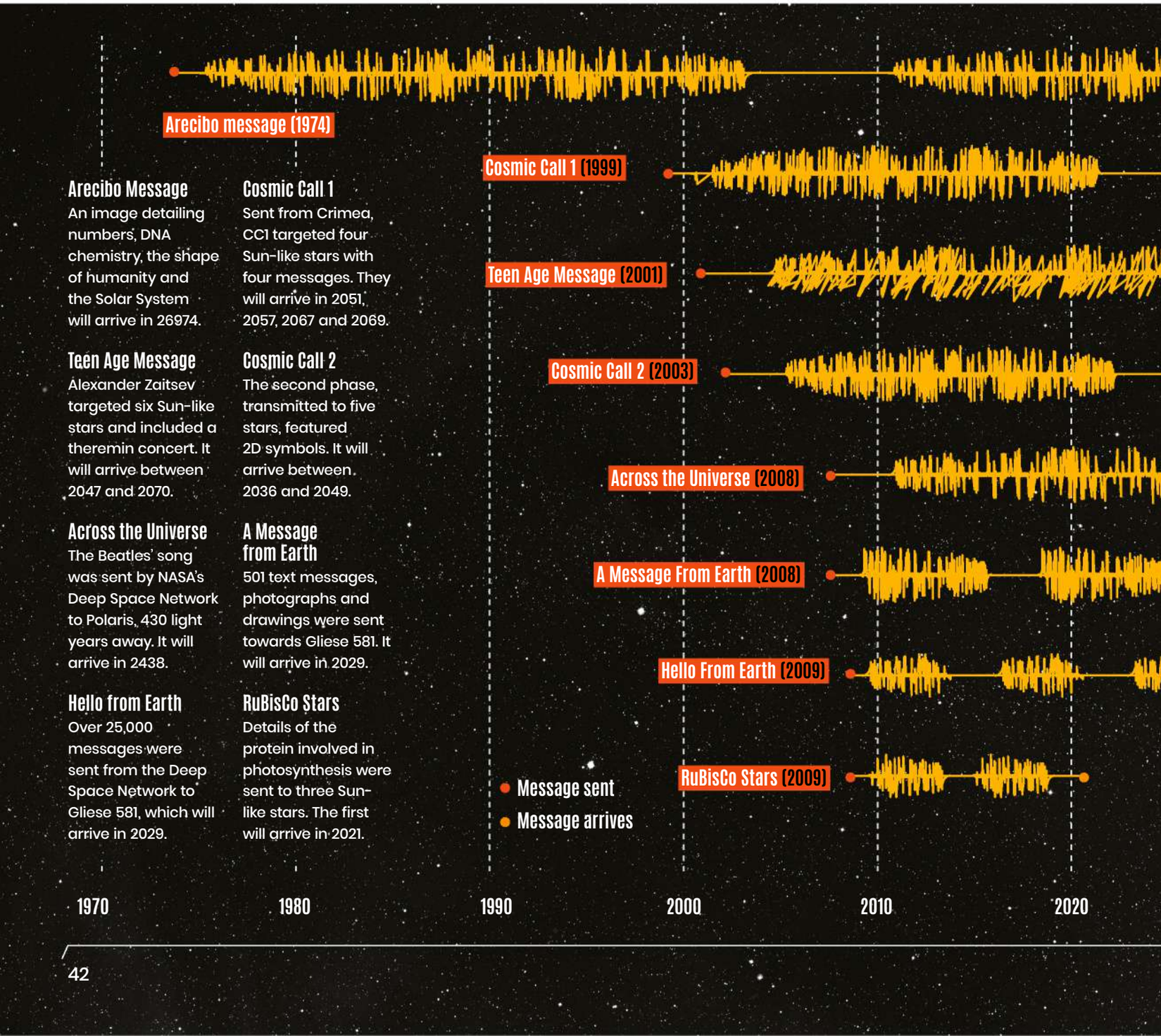
INSTANT EXPERT

HOW FAR HAVE OUR MESSAGES TO SPACE TRAVELLED?

As well as listening for signs of alien civilisations, we've tried sending a few direct messages to likely stars, but how far have they gotten?



Arecibo Message

An image detailing numbers, DNA chemistry, the shape of humanity and the Solar System will arrive in 26974.

Cosmic Call 1

Sent from Crimea, CC1 targeted four Sun-like stars with four messages. They will arrive in 2051, 2057, 2067 and 2069.

Teen Age Message

Alexander Zaitsev targeted six Sun-like stars and included a theremin concert. It will arrive between 2047 and 2070.

Cosmic Call 2

The second phase, transmitted to five stars, featured 2D symbols. It will arrive between 2036 and 2049.

Across the Universe

The Beatles' song was sent by NASA's Deep Space Network to Polaris, 430 light years away. It will arrive in 2438.

A Message from Earth

501 text messages, photographs and drawings were sent towards Gliese 581. It will arrive in 2029.

Hello from Earth

Over 25,000 messages were sent from the Deep Space Network to Gliese 581, which will arrive in 2029.

RuBisCo Stars

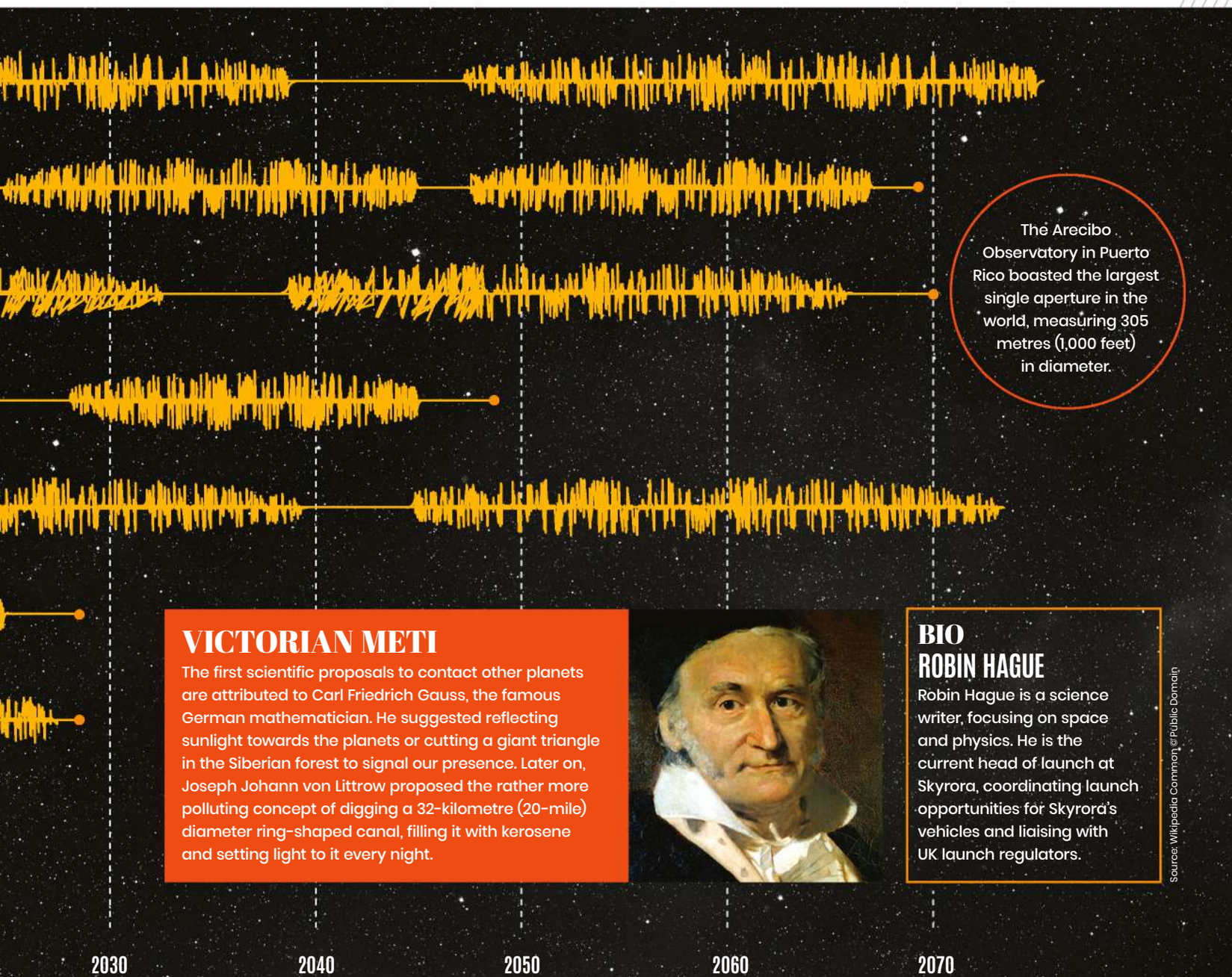
Details of the protein involved in photosynthesis were sent to three Sun-like stars. The first will arrive in 2021.

We continue to listen out for alien civilisations, but a few projects have tried sending specific messages in the hope of attracting communication. As a technological civilisation, we've been sending inadvertent radio noise into space for over 100 years, but to communicate across the stars, radio signals need to be specifically focused and not random.

The first calling card to the stars was the Arecibo Message in 1974, sent towards a globular cluster of stars 25,000 light years away. It was designed by Search For Extraterrestrial Intelligence (SETI) Institute founder Frank Drake and astronomer Carl Sagan as a 210-byte message that can be assembled into a picture. It covered mathematics, DNA, the human form, the Solar System and Arecibo radio telescope.

The 1974 message will take a very long time to reach anyone, but Arecibo also transmitted another message. RuBisCo Stars was created by Massachusetts Institute of Technology (MIT) biological research affiliate Joe Davis for the 35th anniversary of Drake and Sagan's message. This time, however, he sought out stars that Arecibo's fixed dish could transmit to. Teegarden's Star, a red dwarf 12 light years away, became the first system to receive a specific message for extraterrestrial intelligence (METI). The message contained the details of the RuBisCo protein that is critical to photosynthesis, and so almost all life on Earth.

Despite these attempts, the late physicist Stephen Hawking famously advised against advertising our civilisation, pointing out that throughout Earth history, less developed cultures have always come off worse when they are found by more developed ones. Either way, researchers are likely to continue sending messages. One day, perhaps we'll get one back.



The Arecibo Observatory in Puerto Rico boasted the largest single aperture in the world, measuring 305 metres (1,000 feet) in diameter.

VICTORIAN METI

The first scientific proposals to contact other planets are attributed to Carl Friedrich Gauss, the famous German mathematician. He suggested reflecting sunlight towards the planets or cutting a giant triangle in the Siberian forest to signal our presence. Later on, Joseph Johann von Littrow proposed the rather more polluting concept of digging a 32-kilometre (20-mile) diameter ring-shaped canal, filling it with kerosene and setting light to it every night.

Source: Wikipedia Commons © Public Domain

BIO
ROBIN HAGUE

Robin Hague is a science writer, focusing on space and physics. He is the current head of launch at Skyrora, coordinating launch opportunities for Skyrora's vehicles and liaising with UK launch regulators.

2030 2040 2050 2060 2070

CONQUERING SPACE JUNK

Should we be worried about the debris we're leaving in orbit?

Reported by Jonathan O'Callaghan

We humans aren't particularly good at cleaning up after ourselves on Earth, and it turns out we may be even worse when we leave our planet. In over 60 years of space exploration, we've rapidly filled Earth's orbit with junk, and that could become a serious problem in the not-too-distant future. The Soviet satellite Sputnik 1 became our first piece of space junk in October 1957 after it became the first human-made object ever to orbit Earth. By January 1958 its orbit had decayed enough that it re-entered our atmosphere and burned up, never to cause any trouble. But since then we've launched thousands of satellites into space, and many of them have been left in Earth orbit even after they have stopped working.

© Getty

Space junk comes in all shapes and sizes, from bits as small as a fleck of paint to chunks as large as a satellite. More than 8,900 satellites have been launched since Sputnik, and over half are now defunct, orbiting Earth as junk. About 31,000 pieces of debris larger than a baseball are tracked in orbit, but it's estimated there are millions of smaller pieces. Travelling at speeds of more than 28,000 kilometres (17,400 miles) per hour, their size doesn't really matter – all space junk could cause devastating damage if it hit another object.

Space junk, like climate change, is one of those things that's hard to fathom until it's actually a problem. Space is huge, so it seems almost inconceivable that small, human-made objects could pose any sort of problem. However, over the years we've learned that this is anything but the case, with numerous instances of collisions occurring. As a result, Earth orbit can be a dangerous place. So hazardous, in fact, that satellites often need to perform avoidance manoeuvres in order to dodge debris. Satellite operators must move their satellites out of the way if a piece of debris is predicted to head in their direction. Even things as large as the International Space Station (ISS) must be moved now and again. In extreme circumstances, the crew of the ISS get in their spacecraft ready to evacuate in case debris hits the station and causes severe damage, although thankfully no evacuation has ever been required.

Hitting something large can be disastrous, as a number of events over the years have shown. In 1996, part of a French satellite called Cerise was ripped off when it was hit by debris from a ten-year-old piece of an Ariane rocket. This was followed in 2009 by a defunct Russian satellite slamming into a US satellite, shattering both into thousands of pieces that continue to orbit Earth today. But even small bits can pose a problem. In 2016, British astronaut Tim Peake noticed that one of the windows on the ISS had been cracked by a small piece of debris, either human-made or a natural micrometeoroid of some sort. Though not detrimental to the station, it was evidence of the danger posed.

One of the most infamous space debris events came in 2007, when China intentionally blew up one of its own satellites with a missile against international rules.

Some debris, like Skylab and Sputnik, eventually re-enters Earth's atmosphere

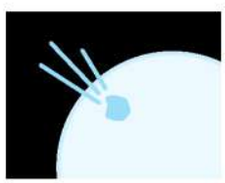
British astronaut Tim Peake spotted a tiny chip in the ISS' cupola window in April 2016

WHY CLEARING SPACE JUNK IS IMPORTANT

Left to orbit Earth, space junk can go from being a nuisance to a deadly missile

Kessler syndrome

This theory suggests that if too much space junk orbits Earth, one collision could cause a chain reaction of collisions as more debris hits other pieces.

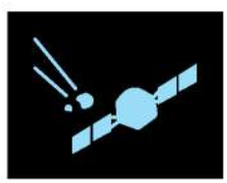


Falling to Earth

Some space junk can reach Earth, such as pieces of NASA's falling Skylab in 1979. The more space junk that's in orbit, the more chance of this happening.

It can hit the ISS

Astronauts on the ISS constantly have to be on the alert for debris. If any is found, the station is moved, and in extreme cases the astronauts will prepare to evacuate.



High speeds

Even tiny pieces the size of a paint fleck can cause damage to satellites because they travel at such high speeds, so efforts must be taken to limit this small debris.

Deadly orbits

If space debris in certain orbits is allowed to build up, it could render those orbits unusable as the debris would present too significant a risk to new satellites.

Satellite impacts

Leaving larger, dead satellites in orbit risks them colliding with others, such as in 2009 when a defunct Russian satellite collided with a working American one.

The anti-satellite test on its Fengyun-1C weather satellite was met with horror as it produced a cloud of thousands of pieces of debris that engulfed Earth within two years. The debris ranges in altitude from a few hundred to a few thousand kilometres above Earth, and some of it is likely to remain in orbit indefinitely. No nation has ever repeated this kind of test, and hopefully never will.

We can track debris thanks to groups like the US Space Surveillance Network, which keeps an eye on the more than 31,000 objects larger than a baseball floating around above us. But the smaller bits, one of which was likely the cause of the crack on the ISS window, are impossible to see. In an effort to get a better handle on small debris, a device called the Space Debris Sensor (SDS) was sent to the ISS in December 2017. Comprising a flat square made of three layers, it's used to monitor how much debris is hitting the ISS. From this it's hoped we can estimate how much smaller debris is in orbit. Protecting against it is much more difficult, however, and spacecraft need to have sufficient layers to ensure that in the event they are hit, what's on board can survive.

In an effort to try and limit the amount of debris in orbit, a number of guidelines have now been put in place. While these won't limit the amount of debris already in orbit, they can help us stop adding to the problem. For example, satellite manufacturers are now required to ensure their satellites burn up in the atmosphere within 25 years of mission completion, either using their thrusters to re-enter or being placed in an orbit that causes enough atmospheric drag to bring them back down.

"British astronaut Tim Peake noticed that one of the windows on the ISS had been cracked by a small piece of debris"

Thankfully, all is not lost for pieces of debris already in orbit. A number of different proposals have been put forward to try and clean up the mess in the hope of doing so in the future. These have included using lasers on Earth to try and push debris back into our atmosphere, where it can burn up. Others

SPACE JUNK BY NUMBERS

12,980
satellites have been launched into Earth orbit since 1957

131 million
Estimated number of bits of debris in orbit

31,000
objects are tracked regularly in orbit

5,400
satellites are intact and operational

25 years
Modern satellites have a set life span

9,900 tonnes
The estimated mass of all space objects in Earth orbit

135
Number of successful rocket launches in 2021

© NASA

EARTH ORBIT TIMELINE

Major events that have led to increased space junk or dead satellites

1978

Kosmos 954

This Russian reconnaissance satellite re-entered the atmosphere on 24 January 1978 after it malfunctioned, scattering some of the nuclear material from its onboard reactor over Canada.

1991

Collision-avoidance manoeuvre

In 1991, Space Shuttle Discovery had to perform the first collision-avoidance manoeuvre – commonly used on the ISS today – firing its thrusters to dodge debris from a Russian satellite.

2007

Chinese anti-satellite test

On 11 January 2007, China carried out this widely derided test, using a missile to destroy one of its own weather satellites, Fengyun-1C, which sent thousands of pieces of debris into Earth orbit.

1996

Cerise military satellite

A piece of debris from an Ariane rocket critically damaged part of this French satellite in 1996, the first confirmed collision of human-made debris in Earth orbit.

2009

Iridium 33 and Kosmos 2251

The deactivated Russian Kosmos 2251 collided with the operational US Iridium 33 satellite on 10 February 2009. Both satellites were destroyed, creating 1,000 pieces of debris larger than ten centimetres.

2013

Fengyun-1C hits the Russian BLITS nanosatellite

In 2013, a small Russian satellite called Ball Lens In The Space (BLITS) was hit by space debris from the Chinese anti-satellite test, an example of the danger of producing new space junk.

2013

Cubesat collision

An Ecuadorian nanosatellite called Pegasus, the nation's first-ever orbital satellite, had a glancing blow in 2013 with debris from a Soviet rocket launched in 1985, sending the satellite spinning out of control.

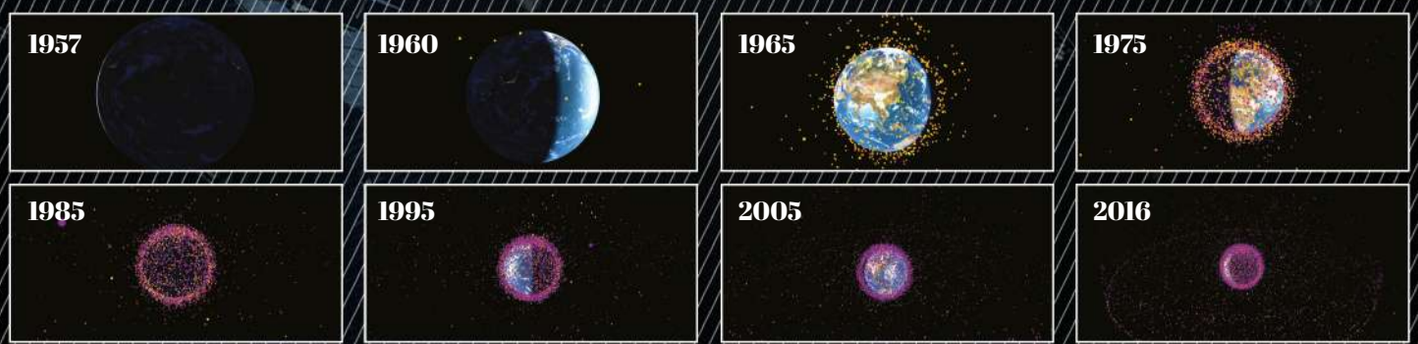
2016

International Space Station window chip

In April 2016, British astronaut Tim Peake noticed a tiny chip on a window on the ISS caused by space debris. Thankfully, it posed no threat to the astronauts on the station.

A GROWING PROBLEM

Dr Stuart Grey of the University of Glasgow created these visualisations to show the accumulation of orbital debris since the dawn of the Space Age



CLEANING UP SPACE JUNK

The proposals that could avert future disasters in orbit

e.Deorbit

This mission was a proposal from the European Space Agency (ESA). It would have involved sending a satellite with a capture device, such as robotic arms or a net, to snag a heavy, defunct satellite in near-polar orbit. The e.Deorbit spacecraft would then perform a controlled atmospheric re-entry to pull the dead satellite into the atmosphere to burn up. Funding was transferred to CleanSpace-1 in 2018.

CleanSpace-1

CleanSpace-1 is an ESA Space Debris Removal proposal to launch a 30-kilogram satellite into low-Earth orbit in 2025. It is planned to grab a defunct Vega payload adapter with a net, demonstrating technologies for rendezvous, capture and deorbit for end-of-life satellites.

Space laser

A paper published by researchers at the Air Force Engineering University in China explores the impact of using a space-based laser to destroy space debris. The team used numerical calculations to target space debris under ten centimetres (3.9 inches) long with 20 bursts of light per second.

KITE

A mission from the Japan Aerospace Exploration Agency (JAXA), KITE launched from the ISS in 2017. The idea was to use an electromagnetic tether to produce a noticeable tug on a Japanese cargo spacecraft, pulling it into the atmosphere. It was suggested this could be used to de-orbit other satellites. The demonstration mission ended in failure when the tether failed to deploy.

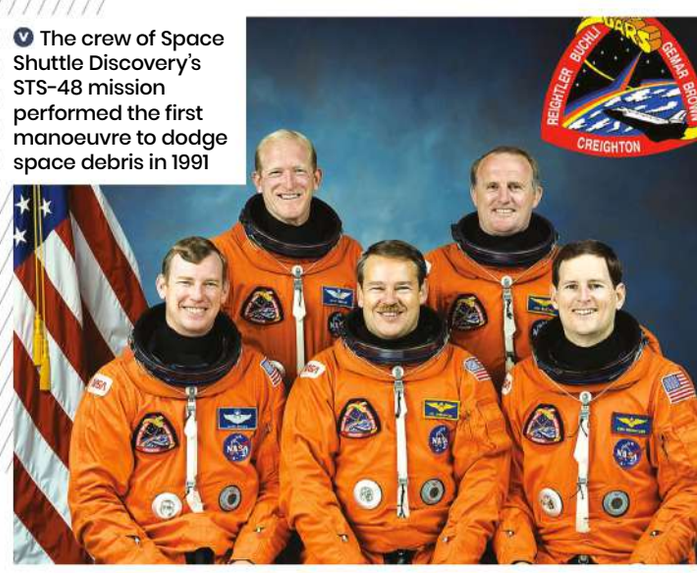
have suggested launching new spacecraft with nets or tethers and using them to snag dead satellites and bring them back down. There are also suggestions to include similar de-orbit measures on new satellites to ensure they don't get stuck in space.

In December 2016 Japan launched a mission to test out such a method. Called the Kounotori Integrated Tether Experiment (KITE), the idea was to extend a tether from a cargo spacecraft and run a current through it. This would create atmospheric drag, producing a tug on the spacecraft that would gradually lower its orbit. Unfortunately the mission ended in failure, but it's still possible that something like this could be included on satellites in the future in order to bring them back to Earth.

This is a pressing concern, as we're launching more and more satellites into space. Everything also points towards a much bigger problem: Kessler syndrome. The idea is that colliding space debris could start a chain reaction of collisions in Earth orbit, destroying more and more satellites and ultimately making some regions all but unusable. It might seem unlikely, but the more stuff we throw into space, the more likely such a scenario becomes. Space junk is a problem that's not going to go away anytime soon, and with more and more satellites being launched into space, the risk of collisions rises. As our ambitions increase, we'll need to prove we're capable of keeping things tidy before it's too late.

Jonathan O'Callaghan
Space science writer
A journalist based in London, his work regularly appears in the *New York Times*, *Forbes*, *Wired*, *New Scientist* and a variety of other publications.

© NASA; ESA; JAXA; Getty



The crew of Space Shuttle Discovery's STS-48 mission performed the first manoeuvre to dodge space debris in 1991

LOST IN SPACE

What's floating around in orbit?

Glove

Lost by Ed White, the first American astronaut to take a spacewalk, on 3 June 1965 during Gemini 4.

200 RUBBISH BAGS

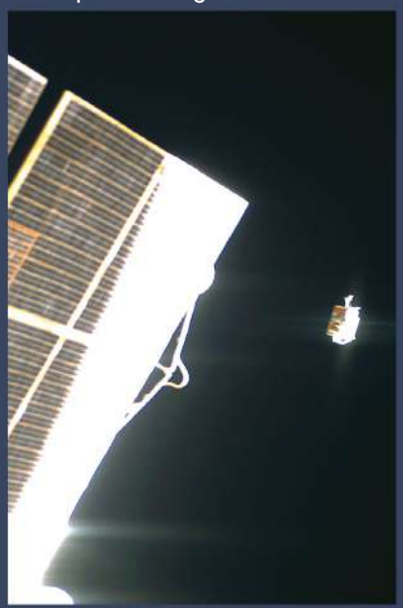
Ejected by cosmonauts on the Mir space station from 1986 to 2001.

CAMERAS

Lost during the Gemini 10 mission and a Space Shuttle Discovery mission in December 2006.

Tool bag

The bag contains grease guns lost by Heidemarie Stefanyshyn-Piper during a spacewalk in 2008. It re-entered the atmosphere in August 2009.



480 MILLION COPPER NEEDLES

Launched in 1963 as part of Project West Ford to create an artificial ionosphere, the needles encircled Earth at 3,700 kilometres (2,300 miles). Some are still in orbit.

Mysterious metallic spherical objects

Started a UFO scare when they crashed in Australia in 1965, but were identified as coming from Gemini spacecraft.

Gene Roddenberry

His ashes were released in a small capsule by a Pegasus XL rocket in 1997.

300,000 FRAGMENTS

Produced when the upper stage of a Pegasus rocket exploded in 1996.

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FOCUS ON

COMETS FADE NEAR SATURN'S ORBIT

It's not just about the Sun's heat

Reported by Elizabeth Howell

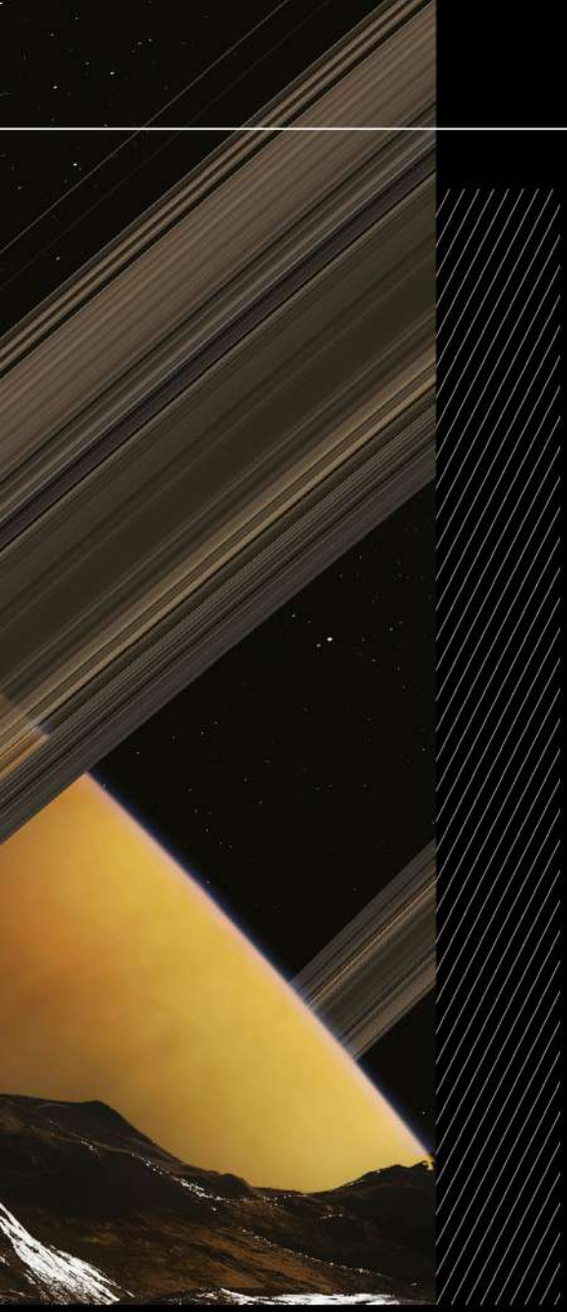
When comets first appear near Earth, their bright tails of ionised gas stun observers, but on every return they become dimmer. Astronomers believed that these objects become dimmer on return because they released too much ice and gas during earlier visits to the inner Solar System. The comets melted and shrank because of the Sun's warmth, so when they return there's less material left to release, and therefore a fainter coma. But a new study by scientists from the University of Oklahoma found that even comets that only skirt the inner Solar System and remain beyond the orbit of Saturn fade over time. That makes no sense as in those far reaches of the Solar System, the Sun's light is so weak that it shouldn't be able to melt a comet's ice.

There must be something going on that changes the physical properties of those comets and leads to their fading. The researchers came to this conclusion when they ran computer simulations of comets travelling through the outer Solar System. Models showed that the powerful gravity of Jupiter and Saturn alters the comets' orbits. The comets may have started their journey following highly eccentric elliptical orbits, approaching from the farthest regions of the Solar System far beyond the orbit of Neptune then hurtling towards the Sun before disappearing back into the outer reaches for centuries. But with every passage near Jupiter and Saturn the comets' orbits become more circular, so they don't retreat as far from the Sun.

"We should expect that the outer Solar System has many more comets on these shrunken orbits compared to those on larger orbits," said Nathan Kaib, an associate professor of astronomy at the University of Oklahoma and lead scientist of the new research. The only problem is that those results don't match what astronomers actually see. "Instead astronomers see the opposite," Kaib said. "Distant comets with shrunken orbits are almost entirely absent from astronomers' observations, and comets with larger orbits dominate our census of the outer Solar System."

To explain this strange absence, the researchers posit that the comets must have faded. Even though they are there, somewhere beyond the orbit of Saturn,

> "We should expect that the outer Solar System has many more comets on these shrunken orbits compared to those on larger orbits" **Nathan Kaib**



they are no longer visible to our telescopes. "Fading among distant comets was discovered by combining the results of computer simulations of comet production with the current catalogue of known distant comets," said Kaib. "These distant comets are faint and extremely difficult to detect, and comet-observing campaigns have taken great pains to build this catalogue over the past 20 years. Without it, this work wouldn't have been possible."

But to understand what exactly is happening would require more powerful telescopes than scientists can use today. Once those are available, Kaib and his colleagues explain, astronomers will probably find out that the outer Solar System is full of faded comets. Astronomers know of comets that orbit between Jupiter and Saturn and regularly burst into powerful eruptions in spite of the cold environment, so it's clear that they can lose their matter even far away from the Sun.

COSMIC SNOWBALLS

Take a close-up look into what makes a comet

1 Nucleus
Spanning up to tens of kilometres in diameter, a comet nucleus is made up of frozen water, gases such as carbon dioxide and methane, organic molecules and dust.

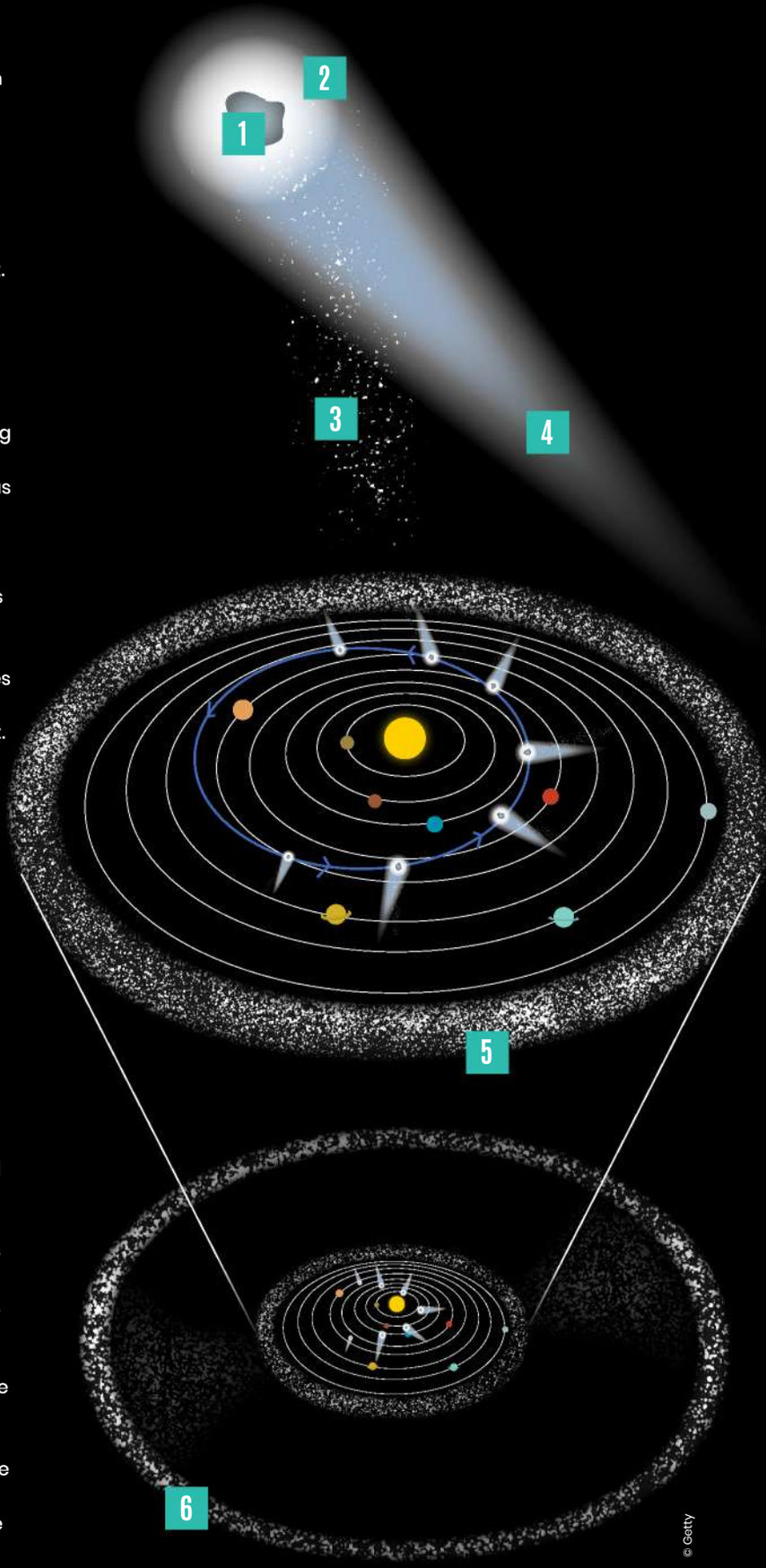
2 Coma
As a comet approaches the Sun its surface sublimates, reducing frozen material into a glowing trail of gas called a coma.

3 Dust tail
A red dust tail is formed when solar radiation pressure moves dust particles into a curved tail following the comet.

4 Plasma tail
The solar wind interacts with the gaseous coma, ionising particles and pushing them away from the nucleus to create a plasma tail.

5 Kuiper Belt
A doughnut-shaped region of space just beyond Neptune that's filled with millions of icy bodies lying 4.5 to 7.5 billion kilometres (2.7 to 4.6 billion miles) from the Sun.

6 Oort Cloud
Surrounding the entire Solar System is a spherical cloud of icy debris as large as mountains. It's thought to be home to many comets.



© Getty

BEYOND THE SOLAR SYSTEM

Five of NASA's spacecraft are heading beyond our solar neighbourhood. What will they find?

Written by Andrew May

When NASA's Cassini mission to Saturn ended in 2017, the spacecraft was deliberately destroyed by crashing it into the planet. The next year, at the end of the Dawn probe's exploration of the asteroid belt, it was placed in a graveyard orbit around the dwarf planet Ceres. These are the two most common fates of interplanetary missions, but there's a third possibility. If a probe has sufficient speed to carry it out of the Solar System and into the space between stars, it can keep travelling forever.

Five probes have ended up on interstellar trajectories so far. Although their designers knew this would happen, it wasn't their main purpose. The first four – Pioneer 10 and 11 and Voyager 1 and 2 – were launched in the 1970s to study the Solar System's outer planets. More recently they've been joined by New Horizons, launched in 2006 en route to the Kuiper Belt, where it flew past Pluto in 2015 and Arrokoth in 2019.

Pinning down the edge of the Solar System isn't easy. By some definitions it might include the Oort Cloud, which surrounds the Sun at a great distance. By common convention, however, 'interstellar space' starts at a point called the heliopause. This is where the Sun's non-gravitational effects – its magnetic field and the solar wind – cease to be discernible against the background of the interstellar medium.

Voyager 1 passed this point in 2012, followed by Voyager 2 in 2018. The other three probes will follow over the next few decades, although we don't know exactly when, as the heliopause tends to drift about in an unpredictable way.

VOYAGER 1 & 2
THE GRAND TOUR

The idea behind the Voyager project originated in 1964, when NASA scientists noticed that an unusual planetary alignment would occur in the late 1970s, allowing a single spacecraft trajectory to pass close to Jupiter, Saturn, Uranus and Neptune in turn. The gravitational boost acquired at each encounter would send the probe on its way to the next planet. Initially dubbed the 'Grand Tour', the mission went through various design changes as NASA struggled to match scientific aspirations to the available budget. In the end, two virtually identical spacecraft were launched: Voyager 2 on 20 August 1977, and Voyager 1 – on a faster trajectory which saw it reach Jupiter first – 16 days later.

Although the Grand Tour could have been completed with a single spacecraft, there were advantages in using two. First, it meant one of them could take greater risks. For example, Voyager 1 got twice as close to Jupiter, with its hazardous radiation field, than Voyager 2, which erred on the side of caution. When Voyager 1 reached Saturn, NASA also wanted to explore its intriguing moon Titan, but this diversion prevented Voyager 1 from reaching Uranus and Neptune – a task that was left for Voyager 2.

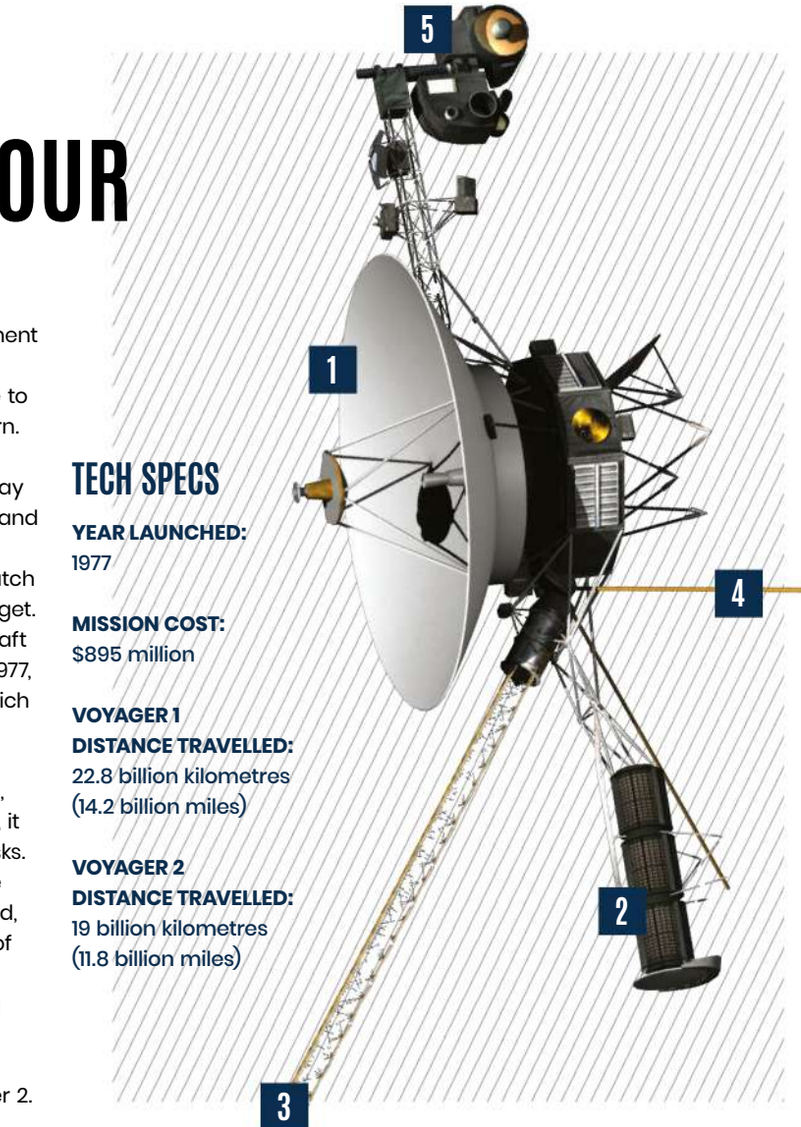
TECH SPECS

YEAR LAUNCHED:
1977

MISSION COST:
$895 million

VOYAGER 1
DISTANCE TRAVELLED:
22.8 billion kilometres
(14.2 billion miles)

VOYAGER 2
DISTANCE TRAVELLED:
19 billion kilometres
(11.8 billion miles)



VOYAGER 1 & 2

The suite of instruments carried by the twin Voyager probes

1 High-gain antenna
This powerful dish antenna, 3.7 metres (12 feet) in diameter, is how the spacecraft sends data back to Earth.

2 Radioisotope thermoelectric generators (RTGs)
There are three of these – essentially batteries powered by radioactivity – providing the spacecraft with electric power.

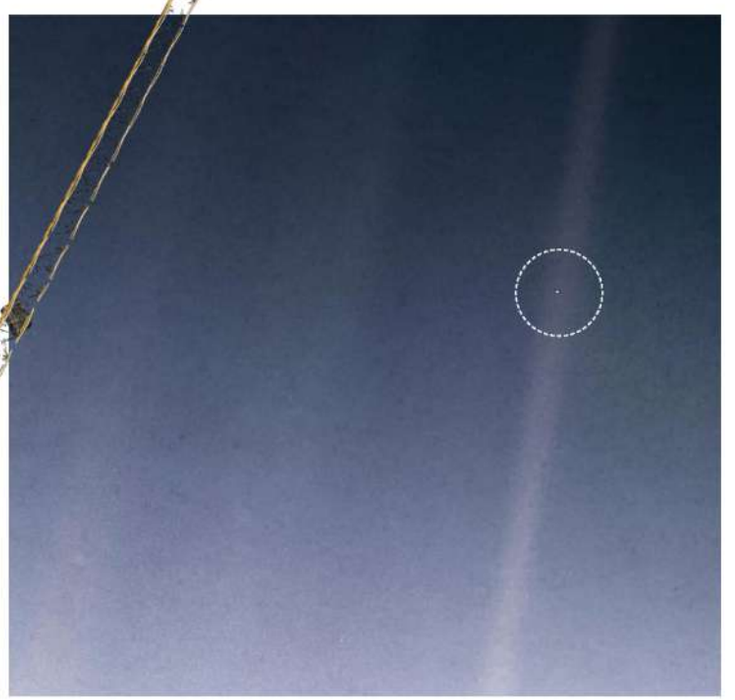
3 Magnetometer
This measures planetary magnetic fields and their interaction with the solar wind.

4 Planetary radio astronomy
These antennae measure radio emissions from the giant planets and can also study plasma waves in their magnetospheres.

5 Imaging instruments
This cluster contains eight separate instruments, including cameras and spectrometers in different wavebands.

VOYAGER'S GOLDEN RECORD

Knowing the Voyagers would venture out into interstellar space, NASA decided to include messages from Earth in case they were intercepted by another civilisation in the future. These take the form of old-style LP records, one on each spacecraft, made not from vinyl but gold-plated copper. They include greetings in 55 languages, a selection of natural 'sounds of Earth' and 27 music tracks from different cultures. The records also contain a selection of images, encoded in analogue form.



The 'Pale Blue Dot' – Voyager 1's iconic photo of Earth from a great distance away

© NASA

> Pioneer 11 photographed Jupiter from angles impossible from Earth, such as over its north pole

PIONEER 10 & 11
PAVING THE WAY

NASA's Pioneer program, which ran for two decades from 1958 to 1978, involved a series of custom-built spacecraft designed to test out various aspects of spaceflight beyond Earth orbit. Two of these spacecraft, Pioneers 10 and 11, acted as pathfinders for the Voyager project, with both having a focus on spaceflight engineering as much as planetary research.

Pioneer 10 was launched in March 1972, reaching the asteroid belt – the first spacecraft to do so – in July that year. It crossed it unscathed, reaching Jupiter in December 1973 and capturing the first close-up images of its atmosphere and moons. As it passed by, Pioneer 10 used the slingshot effect of Jupiter's gravity to boost it onto an interstellar trajectory. It was the first spacecraft to employ a 'gravity assist' manoeuvre of this type, and the first to acquire escape velocity from the Solar System.

Around a year after its predecessor, Pioneer 11 followed in its footsteps – but with an added twist. As well as acquiring escape velocity, the boost it received from Jupiter put it on course for a flyby of Saturn, which took place in September 1979.

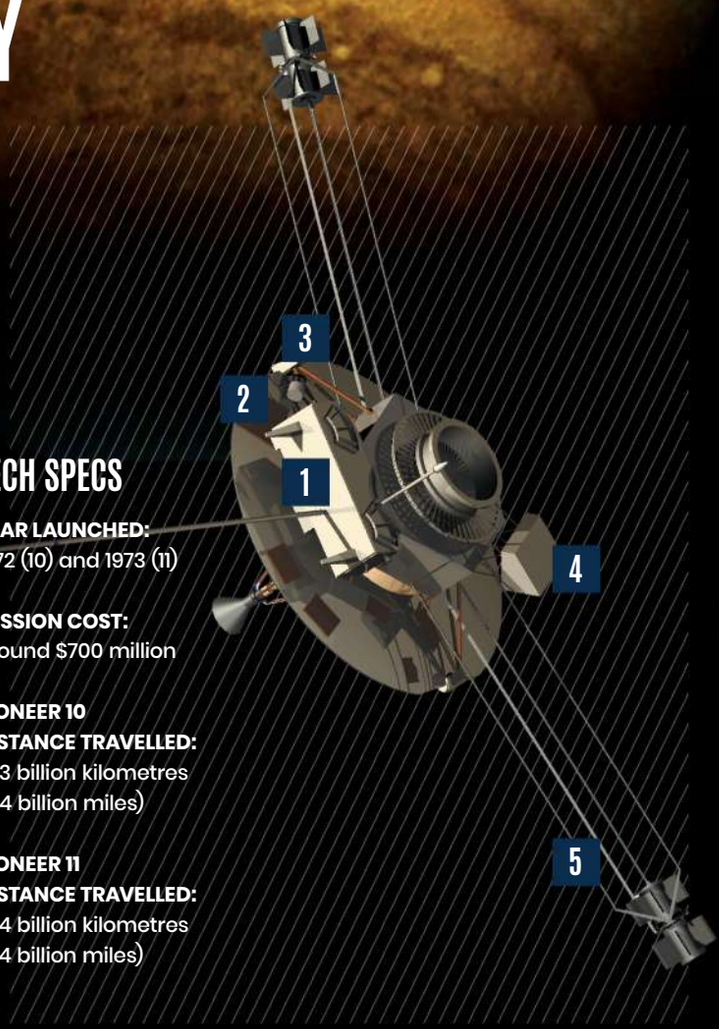
TECH SPECS

YEAR LAUNCHED:
1972 (10) and 1973 (11)

MISSION COST:
Around $700 million

PIONEER 10 DISTANCE TRAVELLED:
18.3 billion kilometres (11.4 billion miles)

PIONEER 11 DISTANCE TRAVELLED:
15.4 billion kilometres (9.4 billion miles)



PIONEER 10 & 11

Similar to Voyager, these had a few distinctive features

1 Plasma analyser
Unlike most of the instruments, which look forwards, this one looks back towards the Sun to study the solar wind.

2 Geiger tube telescope
This measures the distribution of high-energy electrons and protons as the spacecraft passes through a planetary radiation belt.

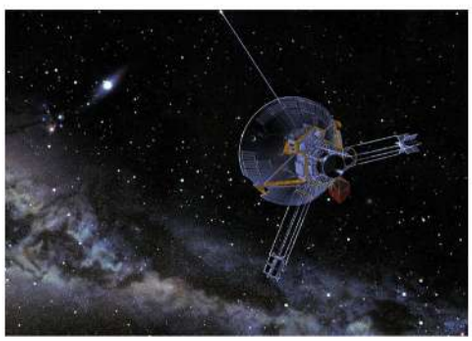
3 Meteoroid detector panels
These 12 panels are mounted on the back of the main communications dish to monitor impacts of micrometeoroids.

4 Asteroid and meteoroid detector
Four small telescopes look out for potential hazards in the form of meteoroids or small asteroids.

5 RTGs
As with Voyager, the Pioneers are powered by radioisotope thermoelectric generators, this time four of them on two separate booms.

PIONEER ANOMALY

One of the remarkable things about long-distance spaceflight is how accurately it can be modelled on a computer. Once clear of Earth, the main force acting on craft is gravity, which behaves in a highly predictable way. It came as a surprise when scientists found Pioneer 10 and 11 were slowing down more quickly than expected from the Sun's gravitational pull. Some thought this indicated a problem with our understanding of gravity, but NASA traced the 'Pioneer anomaly' to an asymmetry in the way they radiated waste heat.



NEW HORIZONS

New Horizons is crammed with scientific instruments for study and observation

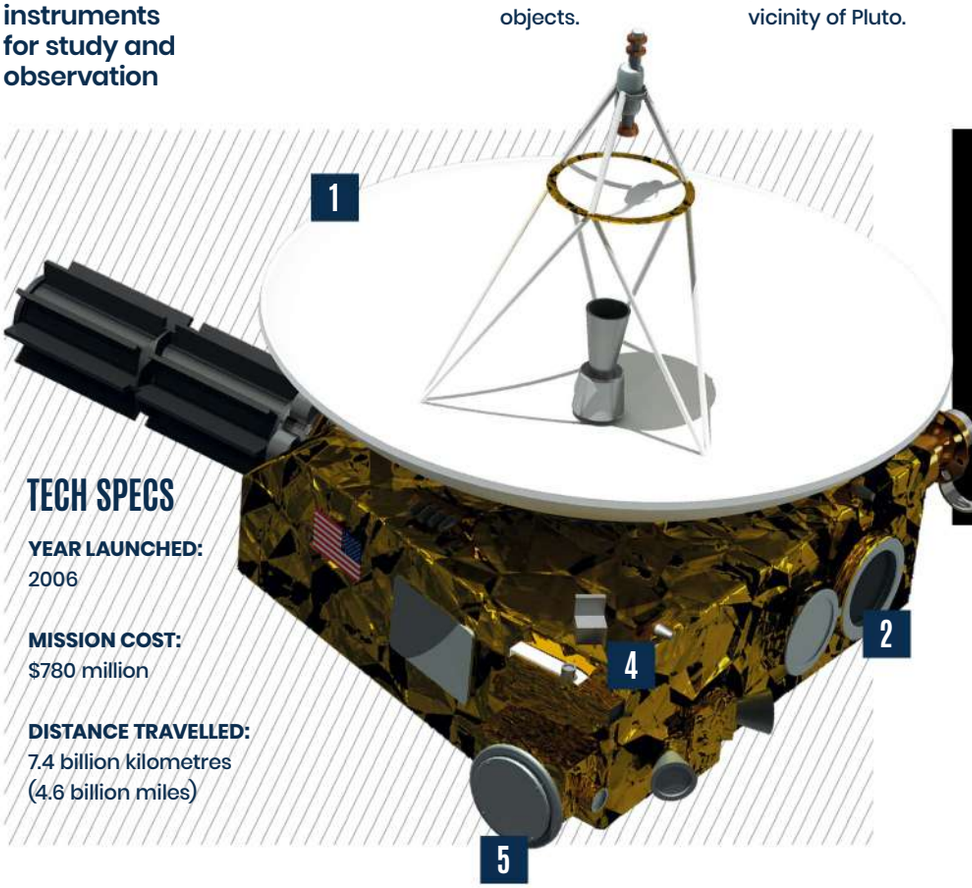
1 Communication antennae
As well as the main high-gain dish, there are two smaller backup dishes nestled inside it.

2 LORRI
The Long-Range Reconnaissance Imager is a telescope used for preliminary studies of more distant objects.

3 Plasma spectrometer instrument suite
These are designed to study high-energy solar wind particles in the vicinity of Pluto.

4 Alice spectrometer
Like Ralph, Alice was named after a character in a 1950s sitcom called *The Honeymooners*.

5 Ralph camera
This is the main imaging device on New Horizons, essentially a compact 75-millimetre-aperture astronomical telescope.

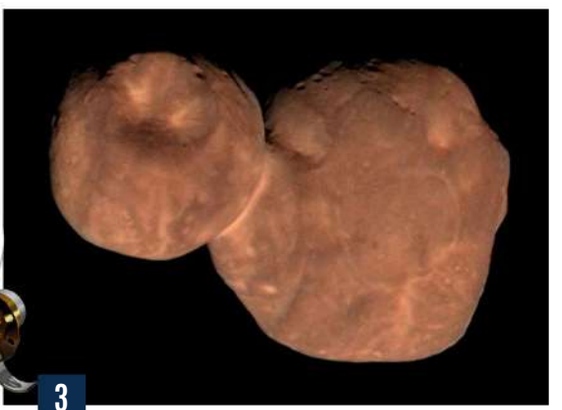


TECH SPECS

YEAR LAUNCHED:
2006

MISSION COST:
$780 million

DISTANCE TRAVELLED:
7.4 billion kilometres (4.6 billion miles)



The oddly shaped Kuiper Belt object Arrokoth

NEW HORIZONS TO PLUTO AND BEYOND

While the Pioneer and Voyager missions focused on the four giant outer planets, New Horizons whizzed past these with barely a glance. Its area of interest lay farther out, in the Kuiper Belt. This distant region of the Solar System, beyond the orbit of Neptune, was hardly known to astronomers when the earlier probes left Earth, but has attracted increasing attention since. For decades the only known Kuiper Belt object was Pluto. This was New Horizons' first destination, which it reached in July 2015 after a journey of nine-and-a-half years.

A flyby of Pluto, rather than Saturn's moon Titan, had been on the cards for Voyager 1, but it lost out because it was expected to be a dead world. The images and data sent back by New Horizons proved how mistaken this was. With an atmosphere, geological activity and possible cryovolcanoes, Pluto is as fascinating as any full-blown planet. Three-and-a-half years after its Pluto encounter, New Horizons passed a second – and much smaller – Kuiper Belt object. Called Arrokoth, it's the most distant body to have been photographed at close range by a spacecraft.

THE FASTEST SPACECRAFT

While the idea of a 'speed record' is clear enough on Earth, things become more complicated in space. Should a spacecraft's speed be measured relative to Earth, the Sun or whichever planet it happens to be closest to? And its speed during an interplanetary mission doesn't necessarily reflect how powerful its rocket engine is. It can also acquire a significant boost from the gravitational slingshot effect as it swings around planets without expending any energy. In terms of initial speed as it left Earth, New Horizons is the fastest spacecraft at 58,537 kilometres (36,373 miles) per hour.

© NASA / Alamy

PLANNING THE NEXT MISSION

How about a dedicated interstellar probe? We speak with scientist Kirby Runyon about a far-flung mission

Runyon is part of a team at the Johns Hopkins University Applied Physics Laboratory working on an Interstellar Probe concept mission that would fly straight out to study interstellar space without visiting any planets on the way.

Why is it important to study the interstellar medium (ISM) in situ?

Finding out how the Sun interacts with the ISM in situ is 'astrophysics you can touch'. To understand the gas, dust and plasma that we can observe – but not touch – surrounding and interacting with other stars, we need to understand how our own Sun's 'weather' is affected by what lies just beyond the Solar System. By having an interstellar probe study the ISM in situ, it will be providing ground truth to both astrophysics and the physics of the Sun.

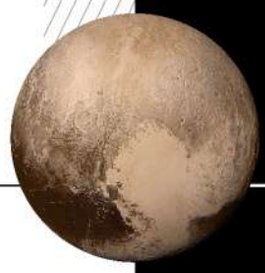
If the project goes ahead, what would the timescale be?

If NASA selects the Interstellar Probe concept, we would hope for a launch in the early 2030s on a 50-year mission to last into the 2080s. Because it would leave the Solar System far faster than any spacecraft to date, it would travel the distance to Pluto in only about four years compared to the almost ten years it took New Horizons.

What are the main engineering challenges beyond New Horizons?

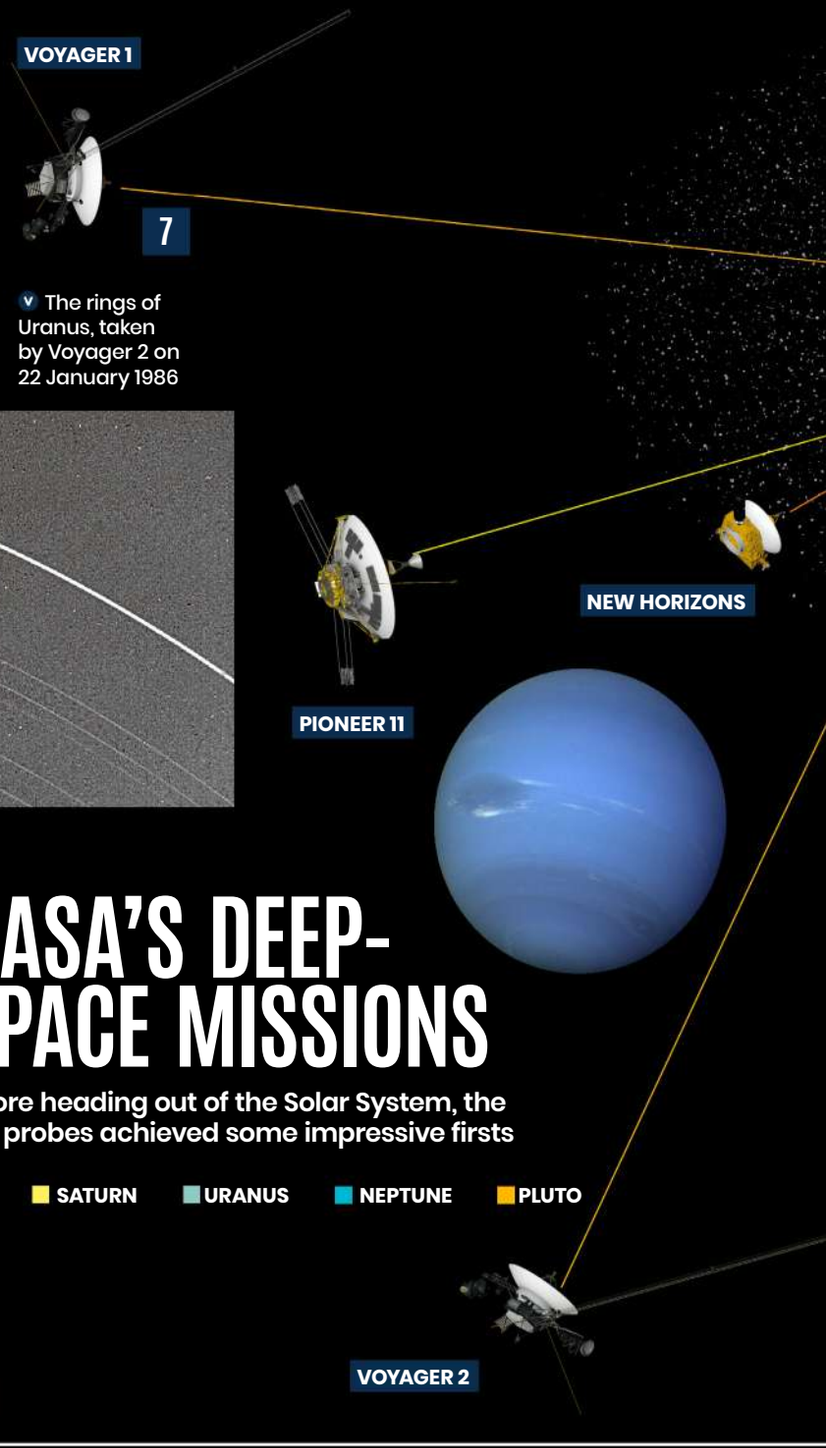
The biggest challenge for such a long-lived, 50-year mission is designing and building a spacecraft that can last that long. Making a long-lived spacecraft means eliminating and reducing moveable parts, which can wear out, and ensuring the spacecraft has enough power from plutonium batteries to last that long. The Voyager craft were designed to last four years, but they've both been operating since 1977 – 45 years! But designing a spacecraft to last multiple decades is very different from a spacecraft 'accidentally' lasting that long.

The rings of Uranus, taken by Voyager 2 on 22 January 1986



NASA'S DEEP-SPACE MISSIONS

Before heading out of the Solar System, the five probes achieved some impressive firsts



3 Dec 1973

First spacecraft to Jupiter

1 Pioneer 10 came close enough to the giant planet to acquire a gravitational boost that ensured it would eventually escape from the Solar System into interstellar space.

1 Sep 1979

Inside Saturn's rings

2 Pioneer 11 flew past Jupiter too, but it then went on to the next planet out, passing within 20,920 kilometres (13,000 miles) of Saturn – well inside the planet's rings.

12 Nov 1980

Exploring the Saturnian system

3 Voyager 1 also visited Jupiter and Saturn, but with much more sophisticated instruments than Pioneer, taking spectacular close-up images of the ringed planet and its moon Titan.

24 Jan 1986

The rings of Uranus

4 Voyager 2 was the first probe to reach Uranus, the icy seventh planet, capturing the first clear images of its faint ring system.

25 Aug 1989

The outermost planet

5 After Uranus, Voyager 2 went on to another ice giant, Neptune – by current definition the Solar System's outermost planet – and discovered five previously unknown moons around it.

14 Feb 1990

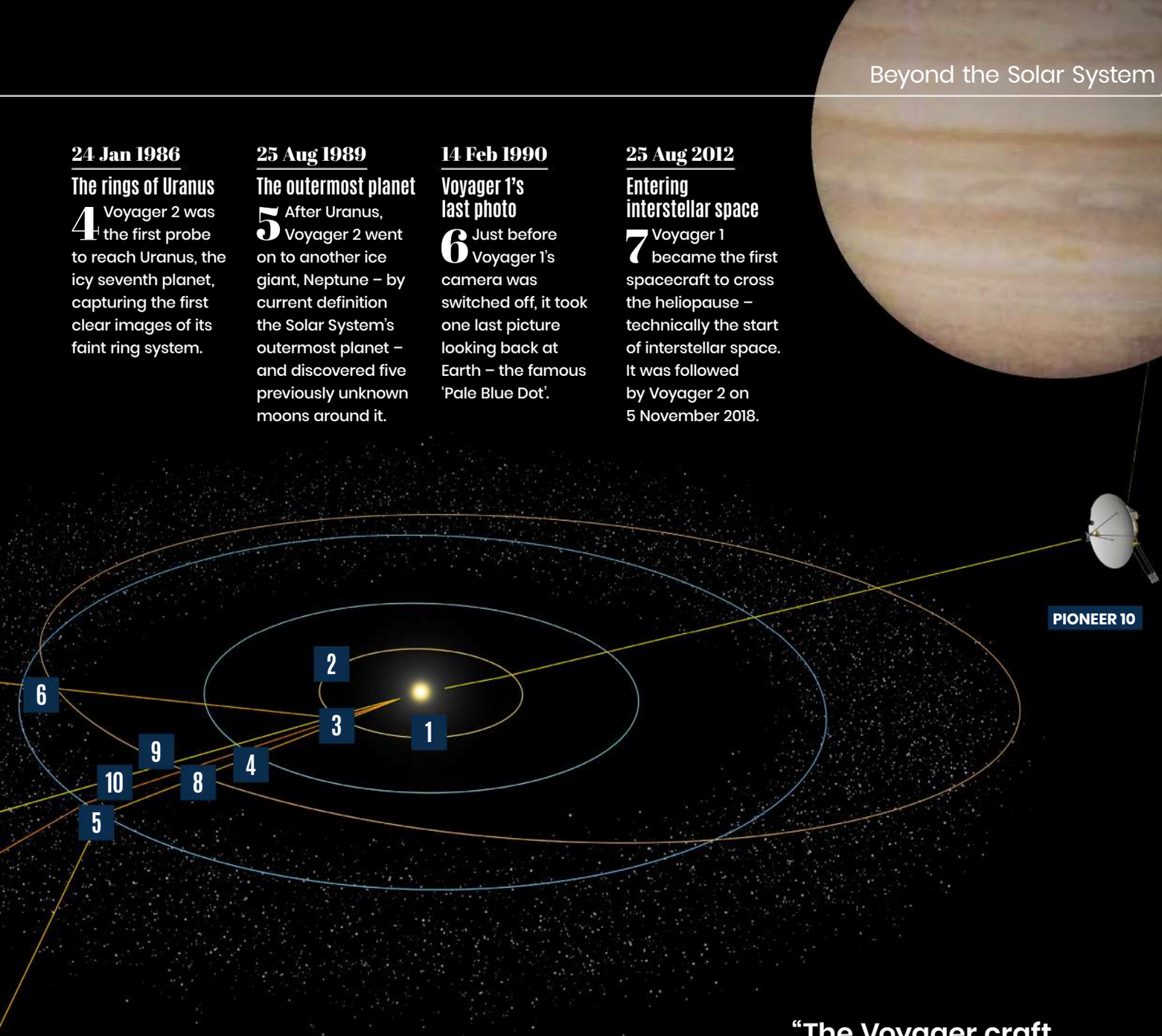
Voyager 1's last photo

6 Just before Voyager 1's camera was switched off, it took one last picture looking back at Earth – the famous 'Pale Blue Dot'.

25 Aug 2012

Entering interstellar space

7 Voyager 1 became the first spacecraft to cross the heliopause – technically the start of interstellar space. It was followed by Voyager 2 on 5 November 2018.



14 Jul 2015

New Horizons at Pluto

8 The closest of the dwarf planets in the Kuiper Belt, Pluto was seen in breathtaking detail when New Horizons passed within 12,500 kilometres (7,770 miles) of it.

7 Aug 2018

The hydrogen wall

9 En route to Arrokoth, New Horizons' forward-looking instruments confirmed the existence of the 'hydrogen wall', a layer of hot hydrogen gas just beyond the heliopause.

1 Jan 2019

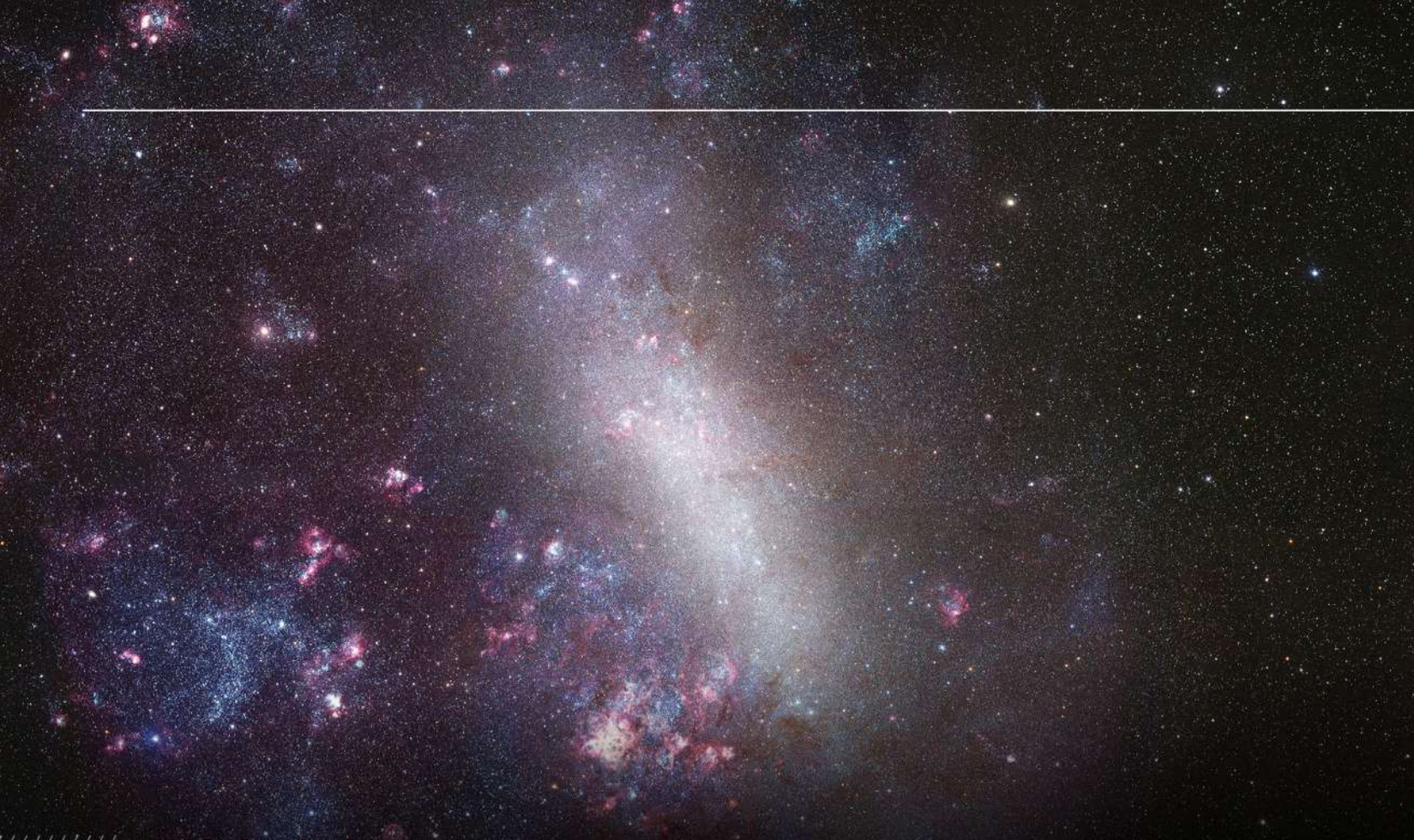
Arrokoth arrival

10 New Horizons' next encounter after Pluto was with a much smaller Kuiper Belt object, known at the time as 2014 MU69 but since named Arrokoth.

"The Voyager craft were designed to last four years, but they've both been operating since 1977" Kirby Runyon

> Saturn, taken by Voyager 1 on 18 October 1980

© NASA / Johns Hopkins APL / Illustration by Adrian Mann



FOCUS ON

OUR SATELLITE'S STARS SHED LIGHT ON GALAXY FORMATION

Mapping of the Large Magellanic Cloud reveals starry secrets

Reported by Samantha Mathewson

Scientists have mapped the motions of stars within the Milky Way's companion galaxy, the Large Magellanic Cloud (LMC), revealing new clues about barred galaxies. The findings could offer new insight into the processes that shape and form the structures of these galaxies, which contain bar-like bands of stars. Located about 163,000 light years from Earth, the LMC – a satellite dwarf galaxy of the Milky Way – is among the closest galaxies to Earth and is visible to the naked eye as a faint cloud in the Southern Hemisphere sky. The LMC is considered an irregular galaxy given its single spiral arm and stellar bar structure, which is offset from the galaxy's centre.

Stellar bar structures are a common feature in spiral galaxies. Scientists think these structures form when small perturbations within the stellar disc strip stars from their circular motions and push them into elongated orbits. "A specific type of these orbits are the ones that are aligned with the major axis of the bar," said Florian Niederhofer, a researcher at the Leibniz-Institute for Astrophysics Potsdam. "These are considered to be the 'backbone' of stellar bars and provide the main support of the bar structure." Using the European's Southern Observatory's (ESO) ground-based Visible and Infrared Survey Telescope for Astronomy (VISTA) in Chile, the researchers studied the motions of stars and their elongated orbits within the LMC. The LMC harbours a variety of stars, ranging from as old as the universe to recently formed,

> "The stunning level of detail in velocity maps shows how much our method has improved"
>
> **Thomas Schmidt**

and its close proximity to Earth makes it the perfect candidate for observing the motions of these stars.

VISTA is designed to survey the southern sky at near-infrared wavelengths. Using the new data, the researchers created detailed velocity maps of the galaxy's internal structure, revealing elongated stellar motions that follow the structure and orientation of the galaxy's stellar bar. "The stunning level of detail in velocity maps shows how much our method has improved compared with early measurements some years ago," study coauthor Thomas Schmidt, a doctoral student at the Leibniz-Institute for Astrophysics Potsdam, said.

VISTA can study individual stars within the LMC, and therefore the processes that shape and form galaxies and their stellar bar structures. The telescope offers a better understanding of stellar dynamics by observing the same stars multiple times over several years in order to measure the stars' proper motion. The study relied on images collected over nine years to discern the minute motions of the stars as observed by the ground-based telescope.

Measurements of the proper motions of stars are needed to determine the full three-dimensional velocities of the stars. However, until now only one-dimensional line-of-sight stellar velocities were available by measuring spectroscopic Doppler shifts – changes observed in the light emitted by a star depending on whether it's approaching or moving away from Earth. "Our discovery provides an important contribution to the study of dynamical properties of barred galaxies, since the Magellanic Clouds are at present the only galaxies where such motions can be investigated using stellar proper motions," Niederhofer said. "For more distant galaxies, this is still beyond our technical capabilities."

GALACTIC EVOLUTION

How different sizes can affect how these gigantic structures form

SMALL GALAXIES

1 A lonely cloud of gas

In order for what astronomers call a 'small galaxy' to be made, a relatively large and isolated gas cloud is needed.

2 The making of stars

Under gravity, the cloud will collapse because there's not enough pressure from the gas itself to fight against this force pressing it down. Baby stars are made in the fight.

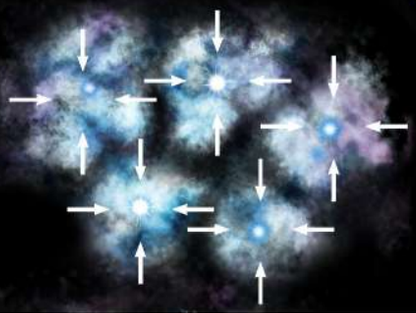
3 Forming a disc

Matter spins quickly, causing a flattened disc-like structure. At the centre is a bulge where older first-generation stars can be found. The rest of the disc is teeming with younger stars.

4 A galaxy with arms

Internal processes make the arms and bars found in spiral galaxies. However, if conditions are more favourable, a lenticular galaxy is made instead.

LARGE GALAXIES

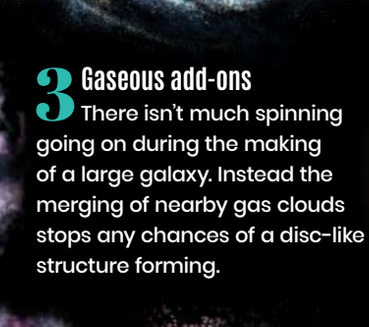


1 A team of gas clouds

Small clouds of gas collapse early on to form the galaxy's very first stars.

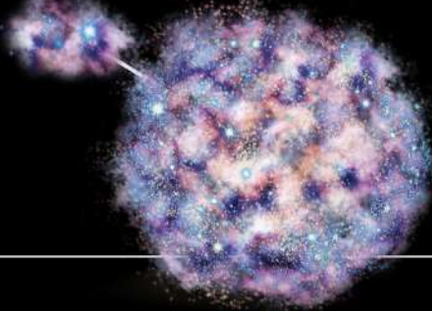
2 A party of stars

These gas clouds and their newly formed stars clump together to make a larger cloud with a party of stellar populations.



3 Gaseous add-ons

There isn't much spinning going on during the making of a large galaxy. Instead the merging of nearby gas clouds stops any chances of a disc-like structure forming.



4 A gigantic galaxy

Since most of the gas was mopped up, no more stars can be made. What's left is a gigantic elliptical galaxy that's dominated by old stars.

© Getty; Nicholas Forder

MYSTERIES OF THE UNIVERSE

SOLVING THE SUN'S BURNING MYSTERY

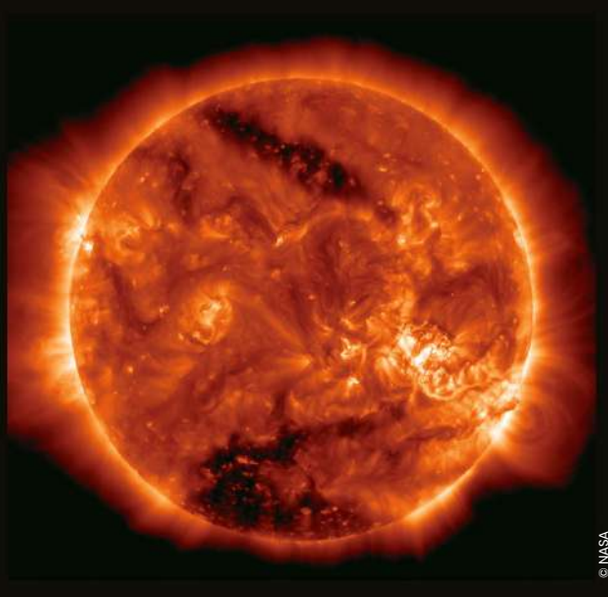
Scientists have spent decades trying to figure out why the Sun's atmosphere heats to extreme temperatures

Reported by David Crookes

Walk carefully over to a fire and you'll find it gets hotter the closer you get. As you walk away you start to feel cooler again. But if you were to do that at the surface of the Sun, the opposite would happen. You'd walk away from the intense heat, start to feel cooler and then suddenly begin to feel hot again. Moving far away from this hot source only puts you in the midst of an even hotter upper atmosphere. Although the Sun's surface burns at a blisteringly hot 6,000 degrees Celsius (10,800 degrees Fahrenheit), the outermost layer of our host star's atmosphere – which extends thousands of miles above the visible surface – reaches temperatures of around 1 to 2 million degrees Celsius (1.8 to 3.6 million degrees Fahrenheit). It's a mystery that's perplexed scientists around the world for decades. Just what is heating the atmosphere to such extreme temperatures? Numerous theories have emerged, each seeking to shed light on the corona's physical properties and how they've come to be. But while the debate rages on, with a number of different promising ideas, astronomers may now be closer to an answer than ever before.

This solar puzzle has a name – the coronal heating problem – and was born in the 1940s. Astronomers had long been investigating the temperature of the Sun by this point, but this was the decade in which the million-degree temperature of the atmosphere was discovered spectroscopically. "As with many other things in space, we know how hot the Sun is by looking at the light that comes off it," explains Dr Jonathan Squire of the University of Otago in New Zealand. "It's just like the intuitive notion we have that 'red-hot' is pretty hot, but 'white-hot' is much hotter. From this we know that the light we see from the Sun is around 6,000 degrees Celsius [10,800 degrees Fahrenheit], and in the corona the same sort of idea applies. Here we look at the light released by specific elements, which emit light at discrete colours. In the corona, it was realised in the 1940s that some of these colours, known as spectral lines, come from iron that has lost many of its electrons, which implies that it must be extremely hot. But why?"

Squire has been working on the problem with Otago's Dr Romain Meyrand and scientists at Princeton University and the University of Oxford. The idea was to get to the bottom of how magnetic fields, which thread out of the Sun's surface, work to heat the gas. "We know from measurements and theories that the sudden temperature jump is related to magnetic fields," Squire asserts. This has been known since the 1960s. "That's when scientists were able to take pictures of the corona in X-rays – it's so hot that it's like a light bulb shining with X-rays rather than visible light, or even ultraviolet," Squire tells **All About Space**. "This showed



Here you can see two coronal holes in the Sun, captured by NASA's Solar Dynamics Observatory in 2015

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THE SUN'S CORONA BY NUMBERS

10 MILLION
times less dense than the surface of the Sun

10 BILLION
times less dense than Earth's atmosphere at sea level

300
times hotter than the lowest layer of the Sun's atmosphere

1 MILLION
Minimum temperature of the corona in Celsius

400
KILOMETRES PER HOUR
Speed at which corona particles are transported through space by solar wind

7,200,000
KILOMETRES PER HOUR
Fastest recorded coronal mass ejection

that the strongest emission, so the hottest gas, was strongly concentrated and shaped by the magnetic field. You can see similar features on pictures of the corona taken during solar eclipses." Since then, he adds, the magnetic field has been measured directly through spectral lines and colours of light, again showing the corona's temperature is directly correlated to the magnetic field complexity. "We can also measure the energy content released upwards in magnetic fields and see that it's more than enough to satisfy the heating requirements."

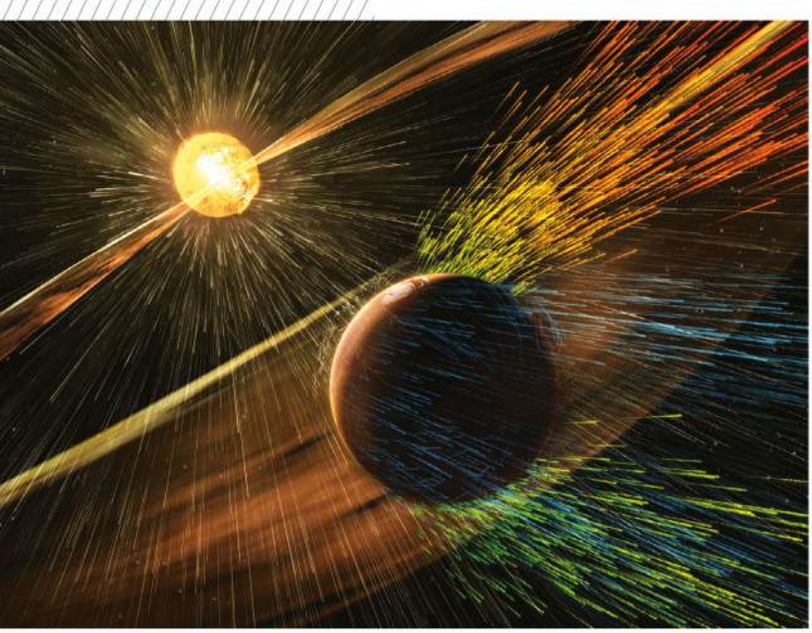
To get to the bottom of this pressing problem, the team examined two well-studied theories – one involving energy transfer and the other a type of magnetic wave – and wondered if they could be linked. On their own, each theory has issues in fully explaining how the corona is able to become so hot. But there was a chance, the team surmised, that one could explain the shortfalls of the other. The method they used was to simulate the coronal gas on a supercomputer, based on a hunch that the two theories would be linked by a new effect called the 'helicity barrier' that was proposed in an earlier study led by Meyrand. It was designed to study a small 'patch' of the corona or solar wind. "Just a tiny box moving outwards with the wind," Squire says. And the main job, he adds, was just to set it up and understand what was happening. "This was a non-trivial task," he adds, "because the simulation made about 30 terabytes of data."

The first theory under scrutiny involved low-frequency Alfvénic turbulence heating the corona through a transfer of energy outwards from close to the Sun. But it has run into problems because what happens in theory is not what is seen in observations. "It's fair to say that there are some issues with theories of heating of turbulence," says Squire. But what are the issues? "Unlike gas here on Earth, different species in the corona can have different temperatures, and this is a bit weird," he explains. "The reason is that particles collide very rarely with each other – hydrogen particles only collide about once in the time it takes them to travel all the way from the Sun to Earth, for instance, so there's nothing to make them have the same temperature."

During turbulence – random, chaotic eddies of gas or plasma – the different particles are stirred up in different ways, causing their temperatures to change. "How this actually happens depends on the conditions that the plasma is in," Squire continues. "When the magnetic field is dominant, like in the corona, the simplest theories of turbulence – backed up by simulations – suggest that electrons should be heated more than hydrogen. But this is the opposite of what we observe." In other words, observations made by telescopes and spacecraft show that the electron-stripped cores of the hydrogen, helium and oxygen atoms, or ions, are becoming superheated while the electrons remain relatively cool in the corona. There have been proposals that seek to get around this difference between theory and reality, but the physics remains poorly understood.

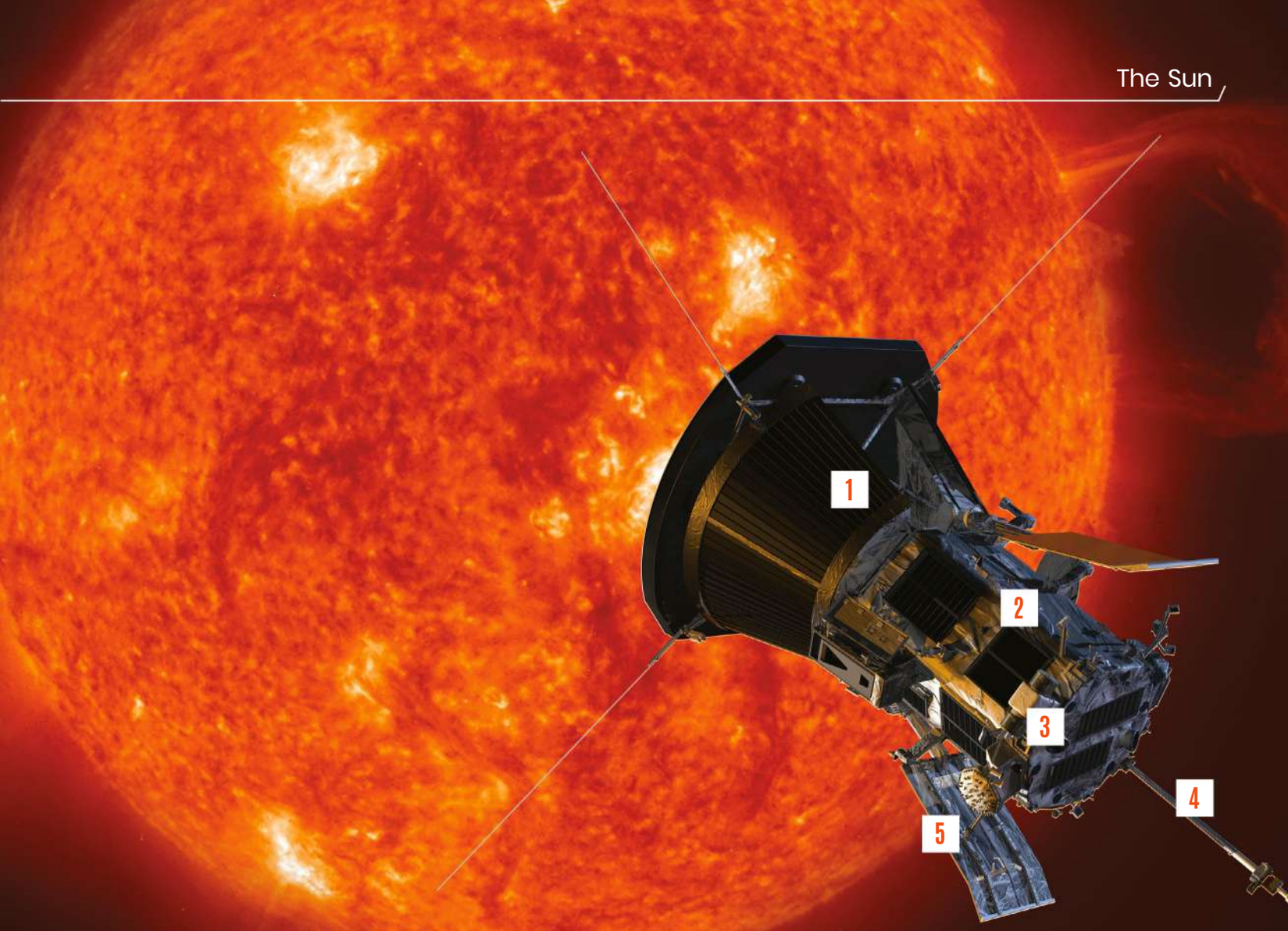
Similarly, a theory that the corona is being heated by a type of magnetic wave called ion cyclotron waves runs into problems for a very simple reason. "For ion cyclotron waves to cause heating, there must be a source of them," Squire says. "There has been good evidence from radio measurements that there are not very many of them coming directly off the surface of the Sun, so that's our fundamental problem – where do they come from?" The simulation borrowed from both theories, showing they are linked by the helicity barrier effect – but what is this?

"One way that physicists think about turbulence is that it's a 'flow' of energy from



The corona, which lies above the chromosphere, can be seen as a halo during a solar eclipse

Understanding the Sun's atmosphere gives scientists a better grip on the solar wind, which can cause damage here on Earth and even on planets further afield



STUDYING THE SUN

NASA's Parker Solar Probe has flown through the corona – the first spacecraft to get so close

1 Taking samples
The Parker Solar Probe was launched in 2018. It flew through the corona to sample particles and magnetic fields in December 2021. There are spikes and valleys that wrinkle the surface.

2 Protection
To enable the probe to withstand the extreme heat of nearly 1,377 degrees Celsius (2,500 degrees Fahrenheit), as well as radiation, it has a thick carbon-composite shield. The payload is at near room temperature.

3 Primary goals
The probe is tracing how energy and heat move through the corona. It's also exploring what accelerates the solar wind and solar energetic particles.

4 Comparative study
Squire and his team say the structures and eddies forming in their simulation are similar to the measurements being taken by the probe.

5 Instruments
The probe's Electromagnetic Fields Investigation instrument captures the shape and scale of electric and magnetic fields. Solar Wind Electrons Alphas and Protons counts solar wind particles and measures its properties.

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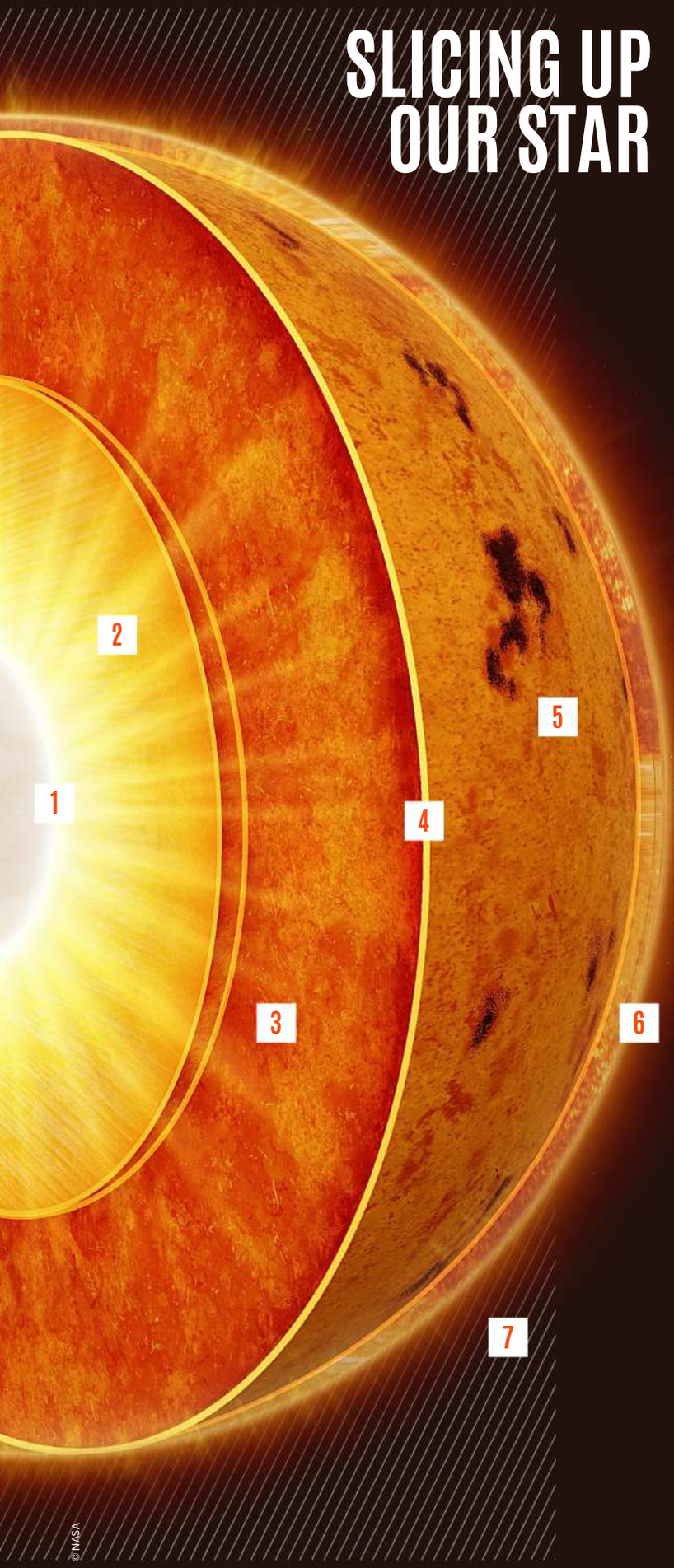
SLICING UP OUR STAR



© NASA

1 SOLAR CORE

Temperature:
Over 15 million degrees Celsius (27 million degrees Fahrenheit)
Density:
150 grams per cubic centimetre

2 RADIATIVE ZONE

Temperature:
1.9 million degrees Celsius (3.5 million degrees Fahrenheit)
Density:
From 20 to 0.2 grams per cubic centimetre

3 CONVECTIVE ZONE

Temperature:
1.6 million to 5,540 degrees Celsius (3 million to 10,000 degrees Fahrenheit)
Density:
$2x10^{-7}$ grams per cubic centimetre

4 PHOTOSPHERE

Temperature:
5,540 degrees Celsius (10,000 degrees Fahrenheit)
Density:
10^{-9} grams per cubic centimetre

5 CHROMOSPHERE

Temperature:
5,540 to 20,000 degrees Celsius (10,000 to 36,000 degrees Fahrenheit)
Density:
10^{-12} grams per cubic centimetre

6 TRANSITION ZONE

Temperature:
22,200 to 1 million degrees Celsius (40,000 to 1.8 million degrees Fahrenheit)
Density:
$2x10^{-13}$ grams per cubic centimetre

7 CORONA

Temperature:
1.1 to 1.6 million degrees Celsius (2 to 3 million degrees Fahrenheit)
Density:
10^{-16} grams per cubic centimetre

THICKNESS OF SOLAR LAYERS

138,400 KILOMETRES

374,980 KILOMETRES

214,040 KILOMETRES

400 KILOMETRES

1,670 KILOMETRES

97 KILOMETRES

5 MILLION KILOMETRES

large scales [big eddies] to small eddies where energy becomes heat," Squire says. To explain this, he draws comparisons with cream in your coffee. "It starts out large scale and unmixed because your spoon is large and makes large eddies, but the motions of stirring break up and twist the cream to smaller scales, and eventually it becomes small enough that the cream mixes into the coffee."

He says that this last step is like the conversion of the magnetic and kinetic energy into heat in the corona. What the study proposes, however, is that something gets in the way of the flow. "The helicity barrier is a very weird feature of strongly magnetised plasmas that stops the process of eddies breaking up. They get smaller and smaller and then suddenly can't any more because of the helicity barrier," Squire continues. "If we imagine the flow of energy to smaller scales to be like a river flowing down a hill, then the helicity barrier is like placing a dam halfway. The energy flow is stopped by the dam, meaning the energy grows because it keeps arriving from larger scales. Eventually, it 'spills over'. This makes some of the magnetic waves that absorb the spillover [the energy], and this last step is what we showed in the simulation. The helicity barrier links the two theories."

The simulation involved emulating the process of the larger eddies stirring up the smaller ones by adding an artificial spoon to stir up the plasma in the box. The scientists watched the turbulence develop and measured its properties as it did so. What's more, the study's findings seem to tally with other data – notably that being gathered by NASA's Parker Solar Probe, which is the first spacecraft to have flown into the solar corona. "The nice thing – and one of the main features of the study – is that when all of this complicated stuff happens with the helicity barrier and the ion cyclotron waves, we serendipitously explain lots of other features that are seen by spacecraft in the solar wind, such as the Parker Solar Probe. "You can see the helicity barrier operating by effectively measuring the shape of the eddies, and we see the same features in the solar wind."

Although Squire and his team stop short of claiming the mystery is solved, they are aware they have made a big step towards better understanding the cause of the heating. And while their work relates to the continuous heating of the corona as opposed to the extreme, bomb-like coronal mass ejections, knowing more about what makes the Sun's atmosphere tick and understanding the solar wind can help us better predict future space weather and avoid devastating problems. "Coronal mass ejections – where part of the corona gets incredibly hot and then explodes out into space – can cause havoc if they hit Earth," Squire says. Indeed, when the solar wind interacts with Earth's magnetic field, it can disrupt satellites providing services such as GPS, affect the power grid, hit radio communications and impact astronauts on the International Space Station. The cost could run into the billions.

"We think we have good evidence of the helicity barrier operating and the process actively occurring, at least in the altitudes of around 20 solar radii, which is now being explored by the Parker Solar Probe," Squire says. "Knowing this, we infer that the heating process – the waves – is also related. This is all a continuous process of comparing our data to observations. If we had the best theory in the world for how it all happened but it disagreed with the observations, then it wouldn't be much good."

David Crookes
Science and technology journalist
David has been reporting on space, science and technology for many years, has contributed to many books and is a producer for BBC Radio 5 Live.

SOME HOT TAKES

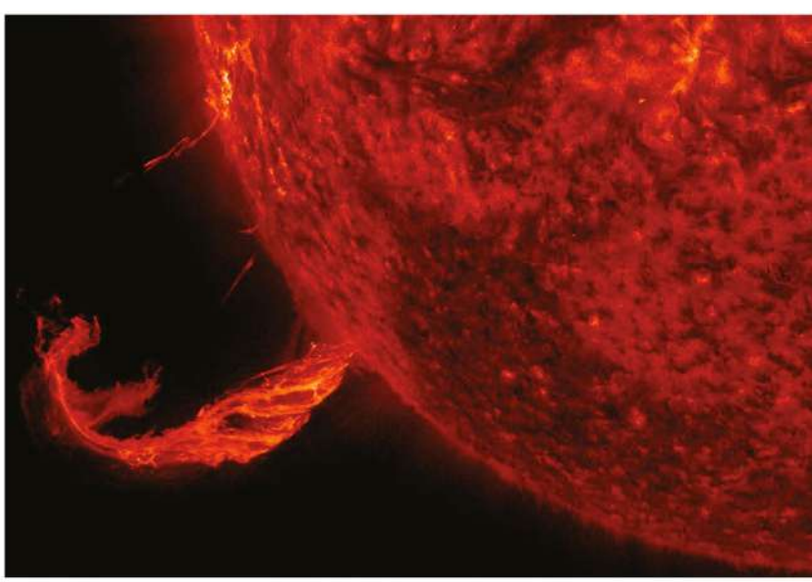
Scientists have come up with a host of hypotheses

Magnetic waves
In 1942, Hannes Alfvén said large amounts of energy could be carried by magnetised waves of plasma from the Sun's surface to the corona along magnetic fields before bursting with heat. The existence of these waves was confirmed in 2021.

Bursts of heat
Tiny eruptions called nanoflares occur in the corona; they are one-billionth the size of normal solar flares. One theory by Eugene Parker says these could be keeping the corona hotter than the surface of the Sun.

Energy transfer
The outer layer of the Sun is in a state of constant turbulence, and it's known that energy is being transferred outwards from the Sun. But observations show that ions are heated more than electrons, and this theory suggests the opposite would happen.

The helicity barrier
The latest study suggests that low-frequency turbulence is halted by an effect called the helicity barrier which limits electron heating and diverts the energy into ion cyclotron waves, which then causes high-frequency heating.



Huge clouds of solar plasma and magnetic fields are sent into space – a coronal mass ejection in action

FOCUS ON

ASTEROID IMPACT UNLIKELY UNTIL 2880

Earthlings can breathe a little easier for the next 800 years

Reported by Elizabeth Howell

A fresh assessment of a distant risky asteroid brings good news: it's even less of a threat than astronomers had feared. The chances of an asteroid dubbed 1950 DA crashing into Earth were always tiny and long in the future. As of 2015, scientists had calculated that the object had a 1-in-8,000 chance of impacting Earth in the year 2880. But a new analysis knocks the asteroid out of the top spot of NASA's list of known asteroids that are potentially hazardous to Earth. "1950 DA shouldn't be of any concern," said Davide Farnocchia, a navigation engineer at NASA's Jet Propulsion Laboratory (JPL) in California. "I'd say that it's encouraging that we can identify the remote possibility of an impact for this object more than 800 years in advance."

The space rock is 1.3 kilometres (0.8 miles) wide, and scientists have a pretty good idea of its shape thanks to observations by the now-defunct Arecibo Observatory in Puerto Rico. Modelling previously suggested that the asteroid is more rubble than rock, which would defuse any possible impact. Fortunately, the new assessment says the asteroid poses even less risk than previously believed. "The probability of impact is tiny – 1 in 30,000," Farnocchia wrote of the asteroid, a substantial improvement from the previous odds. "But even in the very unlikely case that 1950 DA were on an impact trajectory, the possible impact is in 2880, and that provides plenty of time for mitigation," he added.

NASA's mandate includes seeking out and monitoring asteroids like 1950 DA through partner telescopes and space observations, coordinated through the agency's Planetary Defense Coordination Office. There are no impending threats to worry about now, but NASA periodically revisits old assessments to make sure they're accurate. In January the agency upgraded its Sentry system for examining asteroid risk. Among the notable changes were better predictions for the Yarkovsky effect, or alterations to an asteroid's path in space due to heating from the Sun.

The effect has a particularly strong influence on the orbit of 1950 DA, and for years NASA had been calculating asteroid trajectories using a 2002 program called Sentry that couldn't factor in the Yarkovsky effect. Instead Farnocchia and his colleagues would have to simulate a large number of scenarios in what he called "a somewhat brute-force approach". Then the scientists had to analyse the results directly to identify possible impacts and probabilities. When scientists got new observations of 1950 DA, they didn't bother rerunning the impact risks.

However, the upgraded system, called Sentry-II, can account for the Yarkovsky effect, allowing it to automatically calculate impact risks without all the extra work, so 1950 DA got its first new assessment since 2015. The new analysis with Sentry-II only took a few hours and was processed automatically, and will be repeated more regularly. The lower risk assessment moved 1950 DA to second place on NASA's watch list. Now the top spot goes to Bennu, the asteroid that NASA's Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer (OSIRIS-REx) mission sampled in October 2020. The spacecraft will deliver its samples to Earth in 2023, giving scientists a detailed look at the rock and helping them assess whether the asteroid poses any threat.

> "It's encouraging that we can identify the remote possibility of an impact for this object more than 800 years in advance"
>
> **Davide Farnocchia**

IN THE EVENT OF AN IMPACT

A step-by-step guide to what happens if an asteroid is hurtling towards Earth

1 Potential hazard is spotted

Survey telescopes constantly scan the sky for new near-Earth objects. When confirmed, they're added to the list for monitoring, and if they're close to Earth they get priority for closer inspection.

2 Data shared for predictions

If one of the flagged asteroids appears to be on course to strike, information is shared with other observatories and space agencies around the world so that they can compare data.

3 Government and rescue agencies are informed

We'd have about three weeks' notice for a 40-metre asteroid. At this point, experts would inform government and rescue agencies so initial plans could be formulated.

4 Rescue plans and trajectory predictions made

While keeping it quiet from the public, initial safety plans would be put into place while the asteroid's predicted trajectory is updated by observatories around the world.

5 The public are informed

If the data shows the asteroid is still on course to hit, governments in the affected areas would issue safety warnings and instructions for the public two weeks before a strike.

6 72 hours until impact

While rescue plans are still being fine-tuned, it's likely that the government would either issue warnings to take shelter for a smaller strike, or evacuate in the case of a bigger impact.

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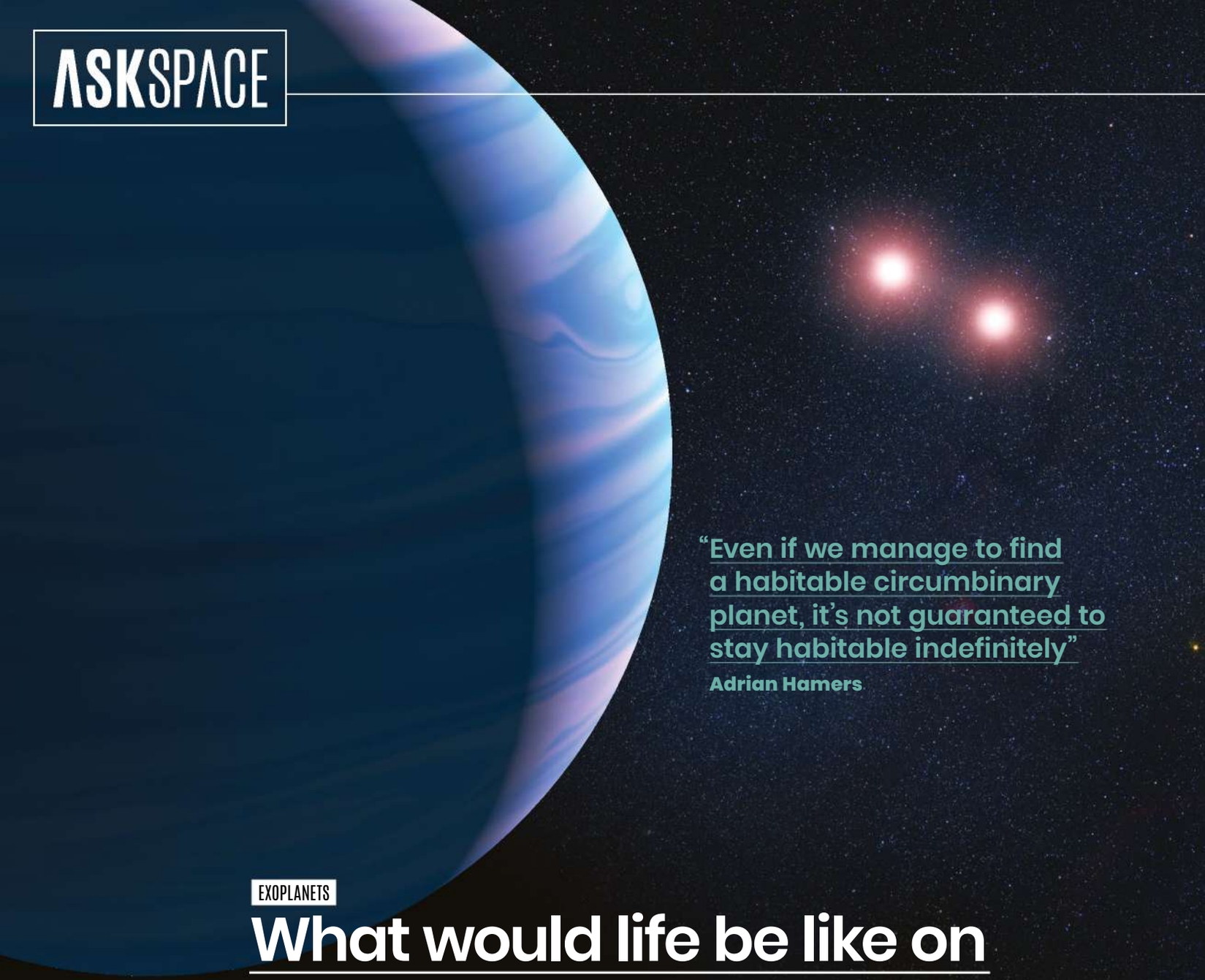

"Even if we manage to find a habitable circumbinary planet, it's not guaranteed to stay habitable indefinitely"
Adrian Hamers

EXOPLANETS

What would life be like on a planet around a double-star system?

Tatooine-like planets – planets orbiting around binary stars, also known as circumbinary planets – are no longer just science fiction. The Kepler spacecraft has observed transiting circumbinary planets. Here we focus on circumbinary-type planets that move around the centre of mass of the double-star system in a relatively wide orbit.

The first requirement for survival on a circumbinary planet is that the planet remains dynamically stable. Gravitational perturbations from the binary can destabilise the circumbinary orbit. If this happens then the circumbinary planet is likely ejected from the system, or it could even collide with one of the stars. Both aren't favourable scenarios for survivability. Secondly, if we agree to need liquid water for survival, and ideally a breathable atmosphere, the circumbinary planet should neither be too close nor too far from the binary.

Even if we manage to find a habitable circumbinary planet, it's not guaranteed to stay habitable indefinitely. Over billions of years the binary stars will evolve. In later stages the stars will lose a lot of mass when they evolve to white dwarfs. The mass loss could unbind the circumbinary planet, hurtling it into the darkness of space. If not, the dim light from the white dwarfs would usher in an indefinite ice age. We are fortunate to be living on a planet that is very accommodating to life.

Adrian Hamers is a postdoctoral fellow at the Institute for Advanced Study in Princeton, New Jersey

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SPACE EXPLORATION

How much does it cost to send someone into space?

There have been different ways to get to and from the International Space Station (ISS) over the years: the now-retired Space Shuttle, the Russian Soyuz spacecraft and SpaceX's Crew Dragon. Costs vary, but the cost per seat is in the region of about £50 to £69 million ($65 to $90 million).

Once you are in space, you need somewhere to stay – that's the ISS – so you need to factor those costs in too. The ISS has cost about £77 billion ($100 billion) since the first plans were drawn up over 30 years ago. This money, however, isn't being spent in space. It's buying the time and expertise of the many tens of thousands of people needed to design, build and operate the ISS, which hosts hundreds of scientific experiments every year. For the ISS, these costs are shared between all the international partners that make up the program, and the UK contributes through the European Space Agency (ESA).

The European Space Agency doesn't buy a flight ticket with money, but instead exchanges contributions to the ISS, and in return NASA flies ESA astronauts. The money that the UK contributes to the European Space Agency comes back to the country in the form of business for a variety of UK companies, which in turn helps grow them and the British economy.

Libby Jackson, human exploration program manager at the UK Space Agency

There are a variety of costs that go into an astronaut's journey

The existence of these dark, dead stars may be proven in the future

STARS

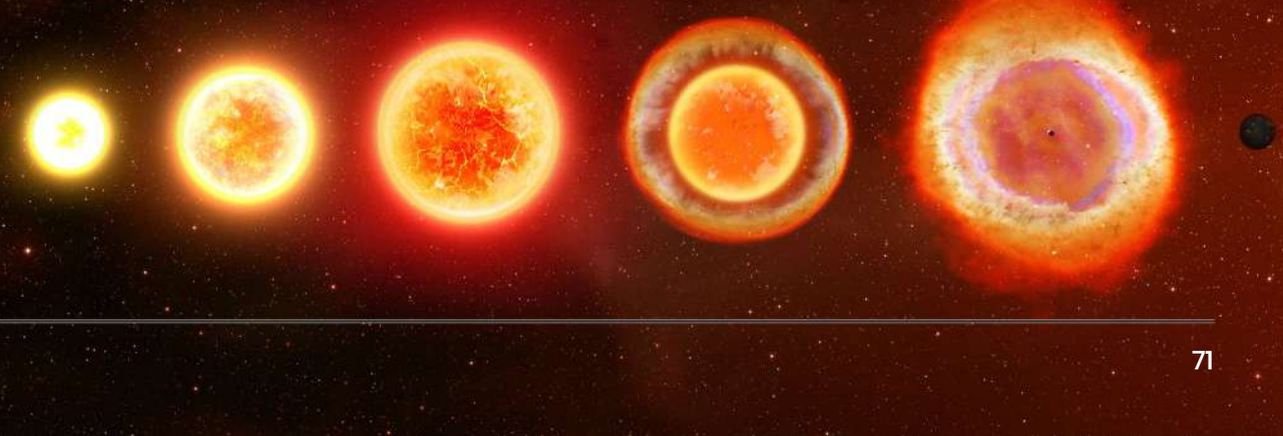
What makes astronomers think black dwarf stars exist?

When a star like our Sun exhausts the fuel in its centre, the core will contract, reaching extreme temperatures of millions of degrees. The star swells into a red giant, but not for long. The heat of the core is so great that it overcomes gravity, lifting off the outer layers of the star in massive stellar winds and exposing the glowing ember of the core: a white dwarf. The exposed core of a star is quite hot, but since they've run out of fuel they can't stay that way forever. Like a cooking pot that's been taken off the hob, all it can do is cool. White dwarfs fade over billions of years as the heat leaks out, carried away by starlight, first turning a dim red colour until eventually vanishing from view entirely. Now dark and frozen, it is said to be a 'black dwarf'. But the time it takes to cool this cold is far longer than the universe has existed – even the oldest, coldest white dwarfs in our galaxy are 5,500 degrees Celsius (10,000 degrees Fahrenheit) and will take billions more years to turn black. While we don't have any black dwarfs yet, their time will inevitably come.

Dr Matt Caplan, professor of physics at Illinois State University

Did you know?

Sirius B is the closest white dwarf to Earth, orbiting in a binary system that lies 8.6 light years away.



ASKSPACE

ASTROPHYSICS

What is a cold quasar?

A cold quasar is a very active supermassive black hole whose host galaxy still has a lot of cold gas in it. The most massive of galaxies with the most massive of black holes become quasars. Quasars are the brightest objects in the universe due to how quickly they are accreting material. This material is super-heated as it swirls around the black hole at nearly the speed of light. This turbulence can produce dramatic winds that sweep through the host galaxy, preventing new stars from being formed and essentially choking the host into becoming a passive, elliptical galaxy.

When we see luminous quasars without any dust in the very centre of the galaxy, the decline in star formation has already begun. Cold quasars were quite a surprise. This rare quasar has swept away dust from the galaxy centre, but the outskirts still have an abundance of cold gas and dust, producing thousands of new stars. Cold quasars are likely at the beginning of the end. The quasar influence is marching through the galaxy; soon the host will lose the ability to form new stars and enter the passive phase of its life.

Dr Allison Kirkpatrick, associate professor of physics and astronomy at the University of Kansas

ASTRONOMY

How do we know the Milky Way is a spiral galaxy?

By mapping the locations, distances and velocities of the stars, we can determine a lot about the Milky Way and its structure, including any spiral arms. We can then reconstruct what the Milky Way would look like to an outside observer. Even without telescopes we are given clues about the Milky Way. Looking up into the night sky, you will see a thin ribbon of stars stretching across, implying that the galaxy is a thin, disc-like shape. With telescopes we can accurately map the positions and velocities of these stars. We see that stars are orbiting the galactic centre in a similar way to the planets orbiting the Sun. Mapping the stars in this way, we can also identify the location of any spiral arms. In the case of the Milky Way, current data shows the presence of four main spiral arms.

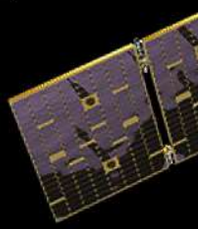
Stephen Molyneux, European Southern Observatory

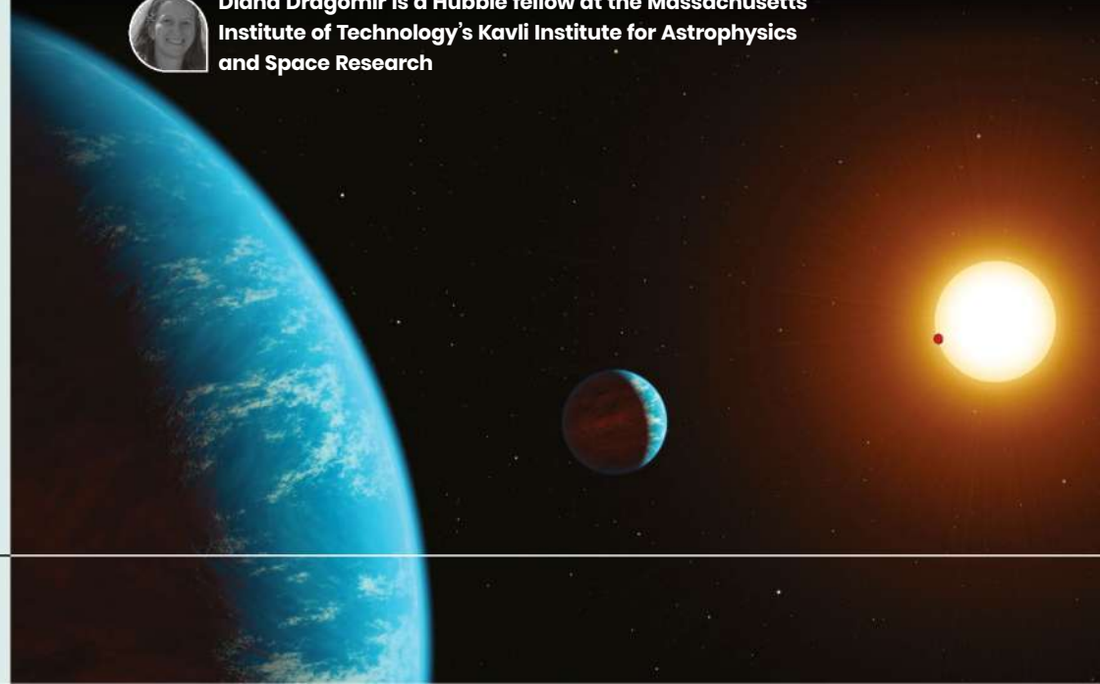
EXOPLANETS

How common are sub-Neptune exoplanets in the Milky Way?

They're pretty common. One really fantastic result from NASA's Kepler Space Telescope was that these small planets – and when I say small, I arbitrarily mean smaller than Neptune – tend to be very common in the Milky Way, at least out to periods that we have been able to probe, so about 50 days. In that sense a planet the size of this one is not very uncommon. A really nice thing is that these exoplanets are really close to us and we can study them, but we know that they're pretty common thanks to Kepler, and we're waiting for one that is close enough that we can actually learn a bit more about it.

Diana Dragomir is a Hubble fellow at the Massachusetts Institute of Technology's Kavli Institute for Astrophysics and Space Research





© NASA ; NASA/JPL-Caltech; ESO; Getty; Michelle Vigeant

Sub-Neptune planets are smaller than Neptune, but larger than Earth

ASTROPHYSICS

How do we know if wormholes exist?

We don't know if wormholes exist, but if they do, it's likely that one day we will find them. Traversable wormholes are unlikely to exist, since there are no known physical mechanisms that can create them or keep them open. A hypothesised form of matter with antigravity effects may keep wormholes open. However, no such exotic matter has ever been observed.

Despite the unlikely odds, some scientists are thinking of how to detect wormholes. Some wormholes are black hole 'mimickers' – they have a positive effective mass, which means they act like black holes. A wormhole may bend the light from a star by passing in front of it in an effect called gravitational microlensing. Other wormholes may have an accretion disc, like supermassive black holes. The light from this disc can encode information about the space-time distortion around the wormhole, which may be different than around a black hole.

It may also become possible to image the shadow of a wormhole directly, just as it was done recently for the black hole in Messier 87. Wormholes may stand out by having differently shaped shadows. The detection of gravitational waves from a black hole merging with a wormhole could also be within reach of next-generation gravitational observatories.

Dr Andreea Font, reader in theoretical astrophysics, Liverpool John Moores University

We might never find one

Did you know?

A wormhole is also called an Einstein–Rosen bridge; they are consistent with the general theory of relativity.

MONEY-SAVING TIPS FOR BUYING A TELESCOPE

Get the best price for your new instrument by shopping smart with these handy tips

Written by Damian Peach and Tom Kerss

When is the best time to buy a telescope? For many enthusiasts, the ideal answer would be right now. If you've got the astronomy bug, then it's never too soon to join the telescope community and explore the wonders of the sky up close. But a realistic answer will always factor in cost and availability, so let's explore how planning and patience can get you a bargain. Unfortunately, telescope prices are on an upward trend due to a variety of factors. Global supply chains have been under exceptional pressure in the wake of the COVID-19 pandemic, while geopolitical events only tighten the squeeze on what can be shipped, and where. This all results in increased production and shipping costs, which are naturally passed on to the customer. It's just another family of goods that's becoming ever more expensive, and it would be naïve to expect prices to 'return to normal' in the near future. If the market survives, higher prices will become the new normal. It's not a lost cause, though. There will always be reductions, and there will always be affordably priced telescopes marketed towards the beginner, some of which are just as appealing to seasoned astronomers.

FIND A GOOD BEGINNER TELESCOPE

If you're looking to buy your first telescope, it's important to understand that it needn't be the flashiest, priciest model. It's better to get started with something robust, simple to operate and small and light enough to enjoy using. Manufacturers which offer a wide range of beginner's telescopes, such as Celestron and Sky-Watcher, haven't escaped sharp price rises, but they still represent the best value for newcomers. Picking something that's suitable for your needs and setting an appropriate budget is a great way to save.

STICK WITH MORE ESTABLISHED BRANDS

There are many inexpensive telescopes on the market, and while some are perfectly acceptable, they're not all made equal. Fortunately, the world's largest brands – Sky-Watcher, Celestron and Orion – all offer excellent budget telescopes at competitive prices. They're long-established companies made up of experts that produce reliable telescopes. Their bundles include mounts, eyepieces and sometimes other accessories, such as finderscopes, that are all good matches for a particular model of telescope, whereas many deceptively cheap brands cut corners to hit such aggressively low prices. It might seem counterintuitive if you're a seasoned deal hunter, but spending a little more money early on will save you from an unsatisfying experience and ultimately save you money, too, since you won't feel the need to upgrade or replace any of the extra components.

THE BEST IS THE ONE YOU USE THE MOST

Larger, more powerful instruments can be cumbersome to set up and usually require more maintenance, so by starting out with a relatively small telescope it's possible to save money and avoid the frustration encountered by those who rush to the deep end. Today's market offers plenty of excellent entry-level beginner telescopes. If your budget is at the lower end and you want to see fainter objects like nebulae and galaxies, consider a Newtonian reflector. They rely on mirrors to give good deep-sky viewing. A six-inch Newtonian is typically comparable in price to a three or four-inch refractor. However, if you're able to spend a bit more, you could consider a five-inch compound telescope, such as a Maksutov-Cassegrain, which is robust, compact and gives good all-round views of a range of objects in the sky.

Some telescopes are better suited for deep-sky observing than others

© Getty

TELESCOPE AVAILABILITY MAY IMPROVE IN SUMMER

The spring and summer months are slower for the telescope market, and in less strained times, availability is better. Astronomical events such as eclipses can inspire short-term themed sales designed to capitalise on the rise in public interest, and certain dates are already earmarked to celebrate astronomy, such as International Astronomy Day, which occurs twice a year in spring and autumn. If you're planning to wait to purchase a particular telescope, you could track its price throughout these events to inform a likely favourable time to buy the following year.

BUY A BARLOW LENS

Many entry-level telescopes are sold with a pair of eyepieces – typically 25mm and 10mm – offering two levels of magnification out of the box. With the addition of an inexpensive Barlow lens, you can increase the size of your eyepiece collection. A Barlow lens doubles the effective focal length of your telescope so that when it's placed in front of the eyepiece it doubles the magnification factor. A 25mm eyepiece behaves like a 12.5mm eyepiece, so you can achieve twice as many different levels of magnification – and each new eyepiece you buy going forward also has twice the value. What's more, many Barlow lenses also include a T2 type thread, designed to accept a T-ring, allowing a DSLR or a mirrorless digital camera to be connected directly to the telescope. Beware of cheap Barlow lenses offering more than 2x magnification, though, as they are often poor quality.

A Barlow lens can increase the usefulness of your eyepieces

PLAN YOUR BUDGET

Telescopes can be bought as complete kits, small bundles or built from individual components. A telescope tube assembly, tripod, mount and one eyepiece are required to start enjoying the sky, but for longevity and value you should budget for some additional accessories, even if this means buying a less powerful instrument. Extra eyepieces extend the range of magnifications you can achieve, and filters and adapters can make a telescope more versatile. Bundles and kits are usually the most cost-effective way to ensure you have what you need to get more performance out of the box and avoid needing to make any further purchases. You might also want to make room in your budget for some books or software to complement your telescope or other accessories that aren't immediately obvious.

THE NEXT SALE IS NEVER FAR AWAY

We live in the age of annual sales, with retailers flocking to join in. They know shoppers are on the hunt for a good deal and they want your custom. With a wide range of retailers carrying popular brands of telescopes, there's always a chance to grab something that's otherwise just out of budget for a favourable price. End-of-year holiday sales and Black Friday usually bring the best offers, but occasionally there are sales connected to astronomy events and space-related festivals. Don't expect huge discounts though, as the margins on optical goods aren't as generous as most other products. However, even when spending a few hundred pounds, a small discount of even ten per cent can be used to purchase an additional accessory or literature to help you make the most of your new home observatory.

WHEN IS THE BEST TIME OF YEAR TO BUY A TELESCOPE?

Telescopes aren't fashion items, so there's no periodic rise and fall in price or availability. They're only temporarily marked down during sales, but if you're willing to be patient and strike when the time is right, your savings can be significant. Even children's and beginners' telescopes can set you back a few hundred, where even ten per cent off adds up. The various popular annual sales are a good place to start. Black Friday has become a days-long shopping event in the retail world, but with the darkening skies of autumn, appetite for telescopes tends to grow, so deep discounts aren't always forthcoming. The same is often true for the January sales, but you might see retailers looking to clear out excess stock after the Christmas rush at this time of year. Telescopes are large items to store, and retailers which carry a wide variety of products would prefer to be rid of any they over-order. As always, it's a good idea to keep an eye on deals during these traditional sale periods.

MAKE YOUR OWN CONNECTIONS

You might be able to make your own luck if you're in touch with a local telescope retailer. Ask them about the possibility of purchasing or reserving an ex-display telescope. In most cases, it'll be in perfect condition. Also, keep one eye on the latest telescope reviews. When a manufacturer releases an updated model, you can expect to see the previous version going for less, just like last year's must-have smartphone. For most of us, it doesn't feel like a good time to spend. Budgets are tight and prices are high, but discounts can always be found, and a properly maintained telescope will bring you many years of fabulous observing experiences. Shop around with patience – the wonders of the sky aren't going anywhere.

"If you're willing to be patient and strike when the time is right, your savings can be significant"

© Getty

WHAT'S IN THE SKY?

What to look at during this observing period

In this issue...

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22 MAY
Conjunction between the Moon and Saturn in Capricornus

22 MAY
The Moon and Saturn make a close approach, within 4°11' of each other in Capricornus

24 MAY
Conjunction between the Moon and Mars in Pisces

24 MAY
Conjunction between the Moon and Jupiter in Pisces

24 MAY
The Moon and Jupiter make a close approach, within 2°53' of each other in Pisces

26 MAY
Conjunction between the Moon and Venus in Pisces

"Asteroid 29 Amphitrite is well placed for observation in Scorpius at +9.8"

26 MAY
The Moon will pass in front of Venus, creating a lunar occultation

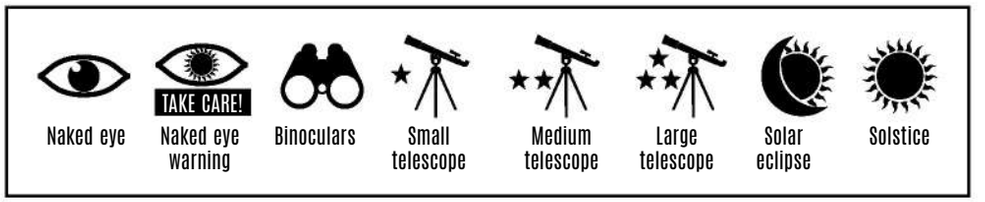
28 MAY
Conjunction between Jupiter and Mars in Pisces

29 MAY
Jupiter and Mars make a close approach, within 34.9' of each other in Pisces

02 JUNE
The Hercules Globular Cluster (Messier 13) is well placed for observation in Hercules

03 JUNE
Globular cluster Messier 12 is well placed for observation in Ophiuchus

06 JUNE
Globular cluster Messier 10 is well placed for observation in Ophiuchus



24 MAY

The Moon and Mars make a close approach, passing within 2°28' of each other in Pisces

26 MAY

The Moon and Venus make a close approach, within 10.9' of each other in Pisces

28 MAY

Globular cluster Messier 4 is well placed for observation in Scorpius

03 JUNE

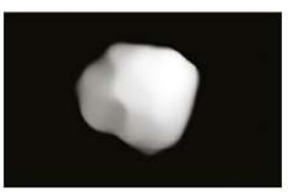
Globular cluster Messier 62 is well placed for observation in Ophiuchus

04 JUNE

Saturn enters retrograde motion

04 JUNE

Asteroid 29 Amphitrite is well placed for observation in Scorpius at +9.8



Red-light friendly

In order to preserve your night vision, you should read our observing guide under red light

11 JUNE

Globular cluster Messier 92 is well placed for observation in Hercules

Jargon buster

Conjunction

An alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Declination (Dec)

How high an object will rise in the sky. Like Earth's latitude, Dec measures north and south in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and 60 arcminutes in a degree.

Opposition

When a celestial body is in line with Earth and the Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Right Ascension (RA)

RA is to the sky what longitude is to Earth, corresponding to east and west. It's measured in hours, minutes and seconds since as Earth rotates on its axis, we see different parts of the sky throughout the night.

Magnitude

An object's magnitude tells you how bright it appears from Earth, represented on a numbered scale. The lower the number, the brighter the object. A magnitude of –1.0 is brighter than +2.0.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongation and as morning stars during western elongation.

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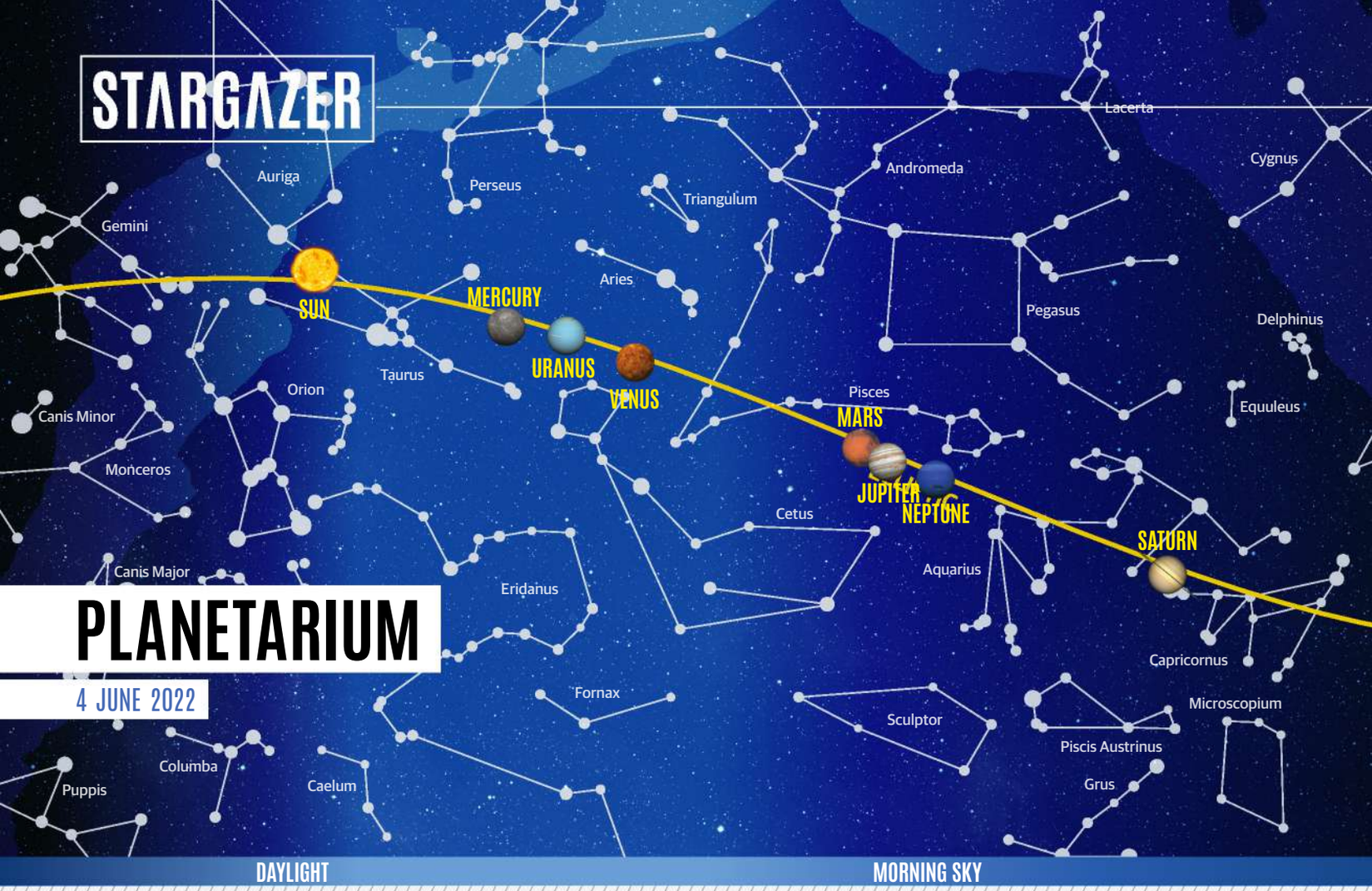


PLANETARIUM

4 JUNE 2022

MOON CALENDAR

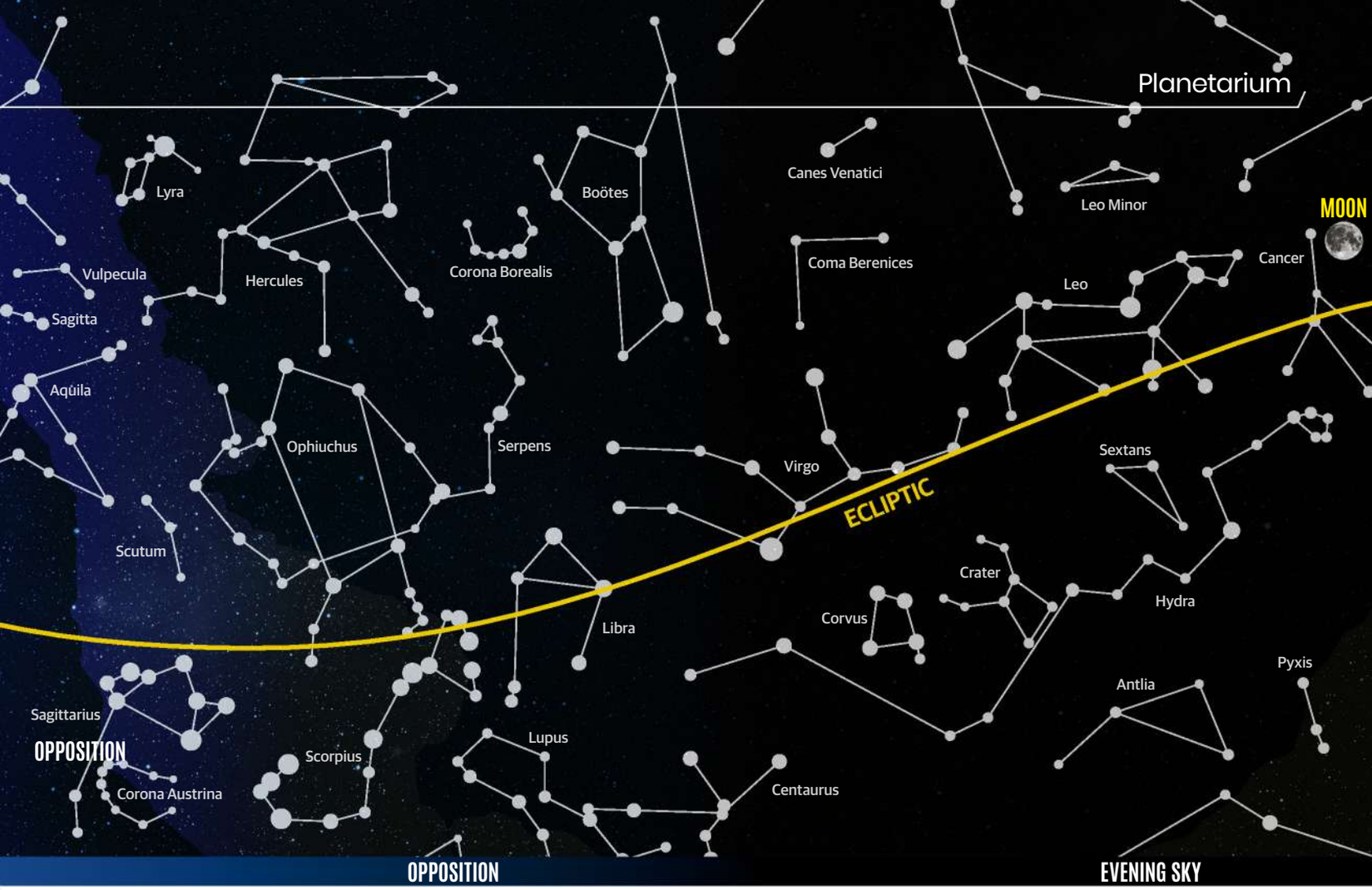
* The Moon does not pass the meridian on 13 June

19 MAY 87.6% 00:26 07:23	20 MAY 78.3% 01.23 08:39	21 MAY 67.5% 02:03 10:04	22 MAY TQ 56.1% 02:30 11:30			
23 MAY 44.6% 02:50 12:52	24 MAY 33.8% 03:06 14:11	25 MAY 24.0% 03:20 15:27	26 MAY 15.5% 03:32 16:41	27 MAY 8.8% 03:45 17:54	28 MAY 3.9% 03:59 19:08	29 MAY 1.0% 04:16 20:21
30 MAY NM 0.0% 04:38 21:32	31 MAY 1.1% 05:06 22:37	1 JUN 4.0% 05:44 23:34	2 JUN 8.7% 06:32 --:--	3 JUN 15.0% 00:19 07:31	4 JUN 22.7% 00:53 08:38	5 JUN 31.6% 01:19 09:49
6 JUN 41.3% 01:39 11:02	7 JUN FQ 51.6% 01:55 12:17	8 JUN 62.2% 02:09 13:32	9 JUN 72.6% 02:22 14:49	10 JUN 82.2% 02:36 16:10	11 JUN 90.4% 02:51 17:35	12 JUN 96.4% 03:10 19:05
13 JUN --:--% 03:35 20:37	14 JUN FM 99.6% 04:11 22:02	15 JUN 99.5% 05:03 23:10	16 JUN 96.1% 06:14 23:59			

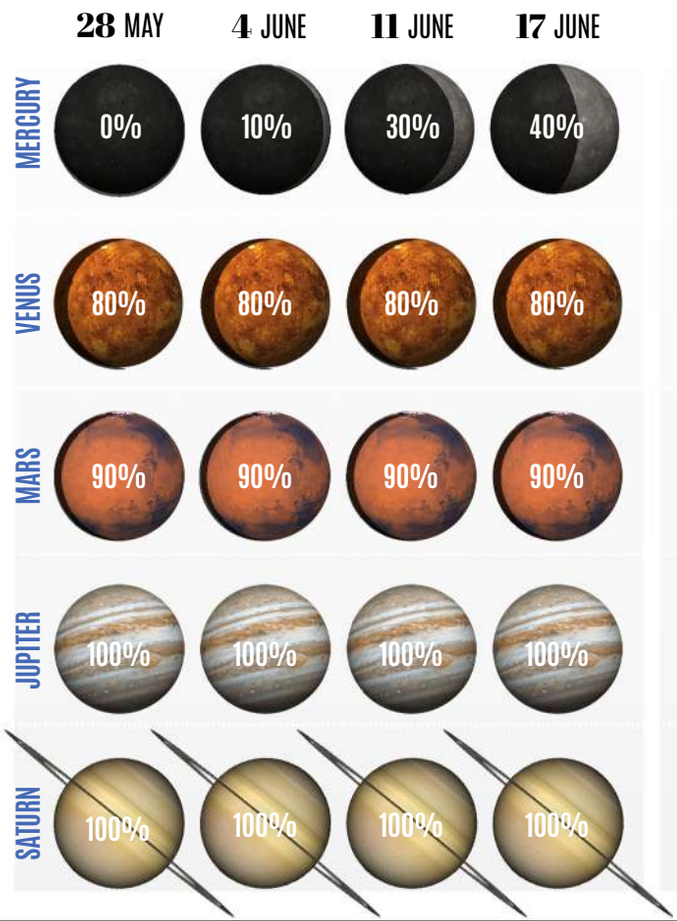
% Illumination
Moonrise time
Moonset time

FM Full Moon
NM New Moon
FQ First quarter
TQ Third quarter

All figures are given for 00h at midnight (local times for London, UK)



ILLUMINATION PERCENTAGE



PLANET POSITIONS

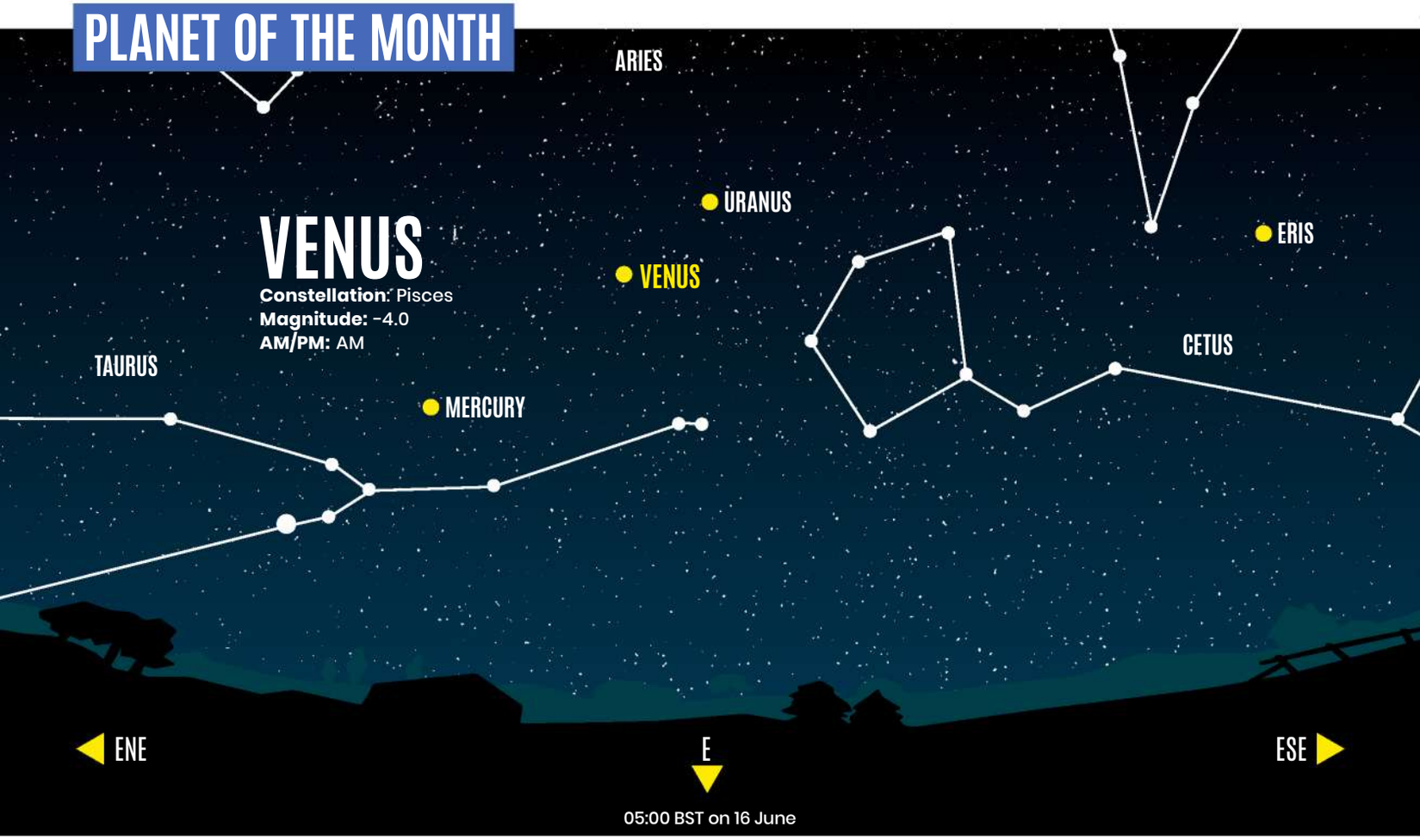
All rise and set times are given in BST

DATE	RA	DEC	CONSTELLATION	MAG	RISE	SET
19 MAY	03h 57m 52s	+19° 44' 53"	Taurus	+6.2	05:49	20:22
28 MAY	03h 40m 51s	+16° 28' 08"	Taurus	+3.8	05:10	19:16
4 JUN	03h 38m 05s	+15° 23' 29"	Taurus	+2.0	04:43	18:39
11 JUN	03h 48m 52s	+16° 00' 14"	Taurus	+0.9	04:23	18:22
17 JUN	04h 08m 47s	+17° 34' 20"	Taurus	+0.3	04:12	18:23
19 MAY	01h 15m 25s	+05° 54' 20"	Pisces	-4.0	03:56	16:41
28 MAY	01h 55m 01s	+09° 38' 47"	Pisces	-4.0	03:47	16:58
4 JUN	02h 26m 32s	+12° 24' 54"	Aries	-4.0	03:41	17:12
11 JUN	02h58m49s	+14° 59' 18"	Aries	-3.9	03:35	17:26
17 JUN	03h 27m 11s	+16° 59' 21"	Taurus	-3.9	03:32	17:39
19 MAY	23h 47m 54s	-03° 08' 39"	Pisces	+0.8	03:01	14:44
28 MAY	00h 12m 38s	-00° 31' 32"	Pisces	+0.7	02:41	14:42
4 JUN	00h 31m 42s	+01° 29' 40"	Cetus	+0.6	02:26	14:41
11 JUN	00h 50m 40s	+03° 28' 54"	Pisces	+0.6	02:10	14:39
17 JUN	01h 06m 51s	+05° 08' 55"	Pisces	+ 0.6	01:57	14:37
19 MAY	00h 06m 53s	-00° 28' 51"	Pisces	-2.2	03:12	15:14
28 MAY	00h 12m 38s	+00° 06' 32"	Pisces	-2.3	02:40	14:47
4 JUN	00h 16m 44s	+00° 31' 23"	Pisces	-2.3	02:15	14:25
11 JUN	00h 20m 27s	+00° 53' 39"	Pisces	-2.3	01:50	14:02
17 JUN	00h 23m 18s	+01° 10' 31"	Pisces	-2.4	01:29	13:43
19 MAY	21h 49m 35s	-14° 17' 25"	Capricornus	+0.8	01:44	12:09
28 MAY	21h 50m 16s	-14° 15' 36"	Capricornus	+0.8	01:09	11:35
4 JUN	21h 50m 27s	-14° 16' 02"	Capricornus	+0.7	00:42	11:07
11 JUN	21h 50m 19s	-14° 18' 06"	Capricornus	+0.7	00:15	10:40
17 JUN	21h 49m 58s	-14° 21' 07"	Capricornus	+0.7	23:51	10:15

THIS MONTH'S PLANETS

Venus takes pride of place in the morning sky alongside the rest of the Solar System's worlds

PLANET OF THE MONTH



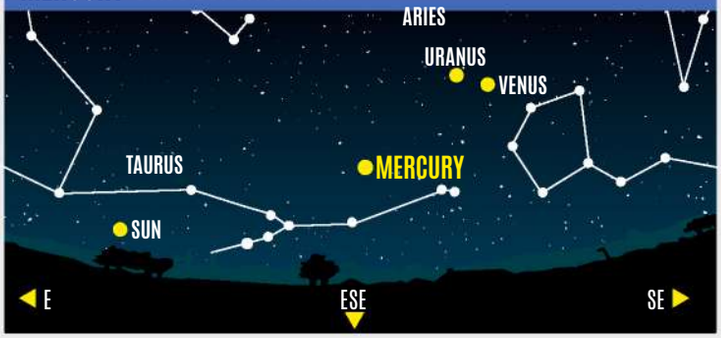
Venus will dominate the morning sky, where an array of worlds, large and small, bright and faint, will be visible, stretched from east to south like beads on a string. Although Venus has always been popular with amateur astronomers because of its brilliance and its beautiful telescopic phases, until recently many planetary scientists considered it a forgotten world, rather lost in Mars' ruddy celebrity light. While probe after probe was sent to Mars – landers, rovers and orbiters – Venus was pretty much ignored. But that's about to change.

In the next few years a veritable fleet of space probes will head for Venus, and if they all work as intended they will provide us with highly detailed maps of its surface and a wealth of information about the composition and workings of its atmosphere. And scientists are dreaming of even more ambitious missions in the future. In years to come we might see balloons carrying payloads of instruments through Venus' acidic clouds, or even a rover driving across its heat-blasted rocky plains, specially armoured to protect it from the planet's crushing surface pressure and furnace-hot temperatures.

Venus is famously known as 'the evening star', but at the moment it's a bright morning star, brighter and more striking to the eye than any other planet or star in the sky. Having said that, its visibility is limited because of its proximity to the Sun and the brightness of the predawn sky at this time of year, but it will still be a striking sight for observers and sky-watchers who have a low, flat horizon to the east without any hills, buildings or trees to hide it and all the other planets from view.

On the morning of 25 May Venus will be joined in the sky by a beautiful waning crescent Moon. Before dawn on 27 May that Moon – by now a thin sliver of a crescent – will be shining directly below Venus; this would be a stunning sight in a darker sky, but with sunrise so near this close encounter won't look as dramatic. On 1 June Venus moves from Pisces into Aries, rising an hour before the Sun.

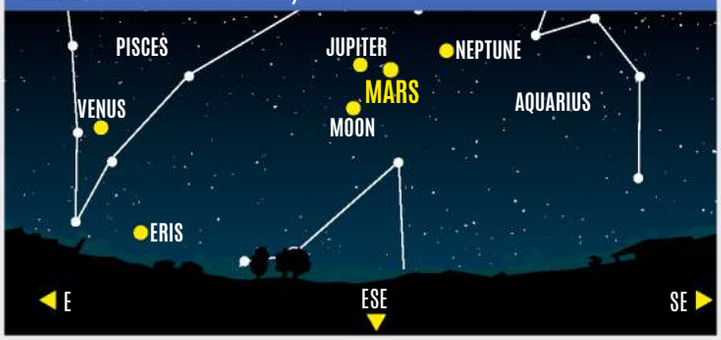
MERCURY 05:00 BST on 10 June



Constellation: Taurus **Magnitude:** +0.6 **AM/PM:** AM

At the start of our observing period Mercury is too close to the Sun to be visible. By the end of May it will have drifted into the morning sky, but will remain too close to the Sun to be seen. By 16 June it will have brightened and will be forming a tight triangle with the Pleiades and Venus, but will be rising only half an hour before the Sun.

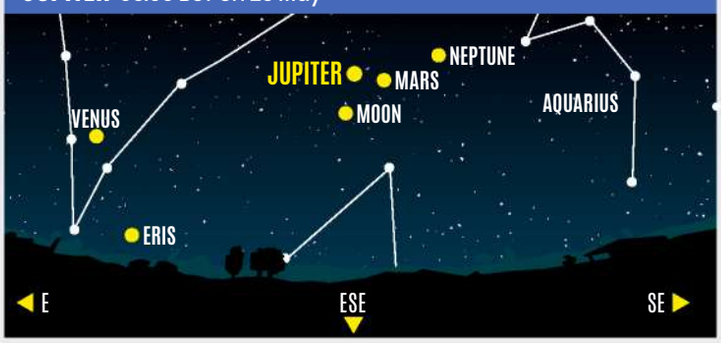
MARS 05:00 BST on 25 May



Constellation: Aquarius **Magnitude:** +0.8 **AM/PM:** AM

Mars is bright enough and far enough away from the Sun to be seen with the naked eye. At the start of our observing period it will be shining less than six degrees to the right of Jupiter, with Saturn further to its right. It will also be very close to Neptune, but you'll need a telescope to see their close conjunction due to Neptune's faintness.

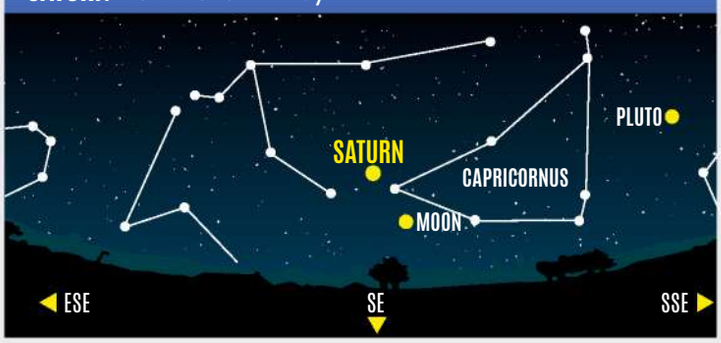
JUPITER 05:00 BST on 25 May



Constellation: Pisces **Magnitude:** -2.2 **AM/PM:** AM

Jupiter will be visible low in the east before sunrise, with Venus blazing to its lower left and Mars shining to its upper right. As May passes Mars will appear to move closer to Jupiter, as will a waning crescent Moon. The three come together on the morning of 25 May to form a triangle that will look pretty in binoculars.

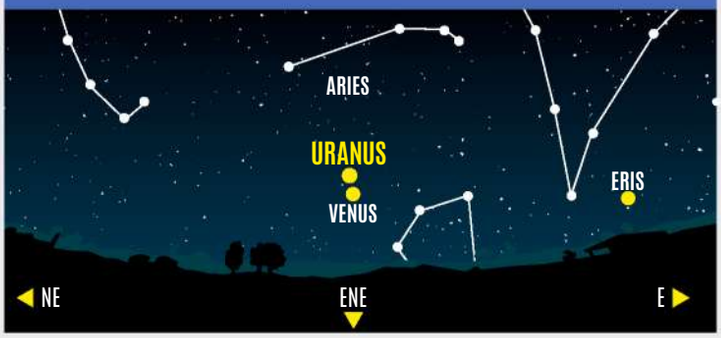
SATURN 03:00 BST on 22 May



Constellation: Capricornus **Magnitude:** +0.8 **AM/PM:** AM

Saturn will be a yellow-white morning star during the month ahead, visible to the naked eye. It will lie at the southern end of a line of worlds stretched out across the predawn sky. At the start of our observing period it will rise two hours before the Sun, which will have increased to three hours by the middle of June.

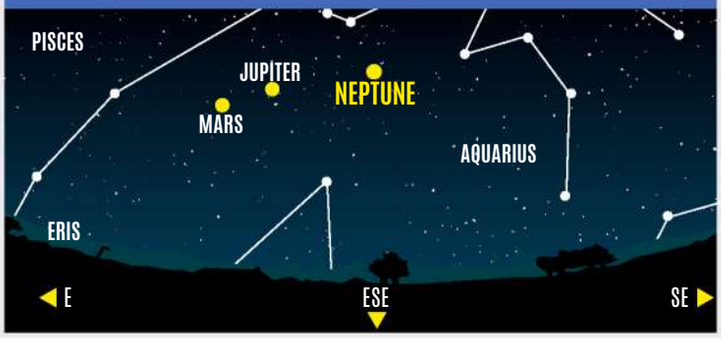
URANUS 04:00 BST on 12 June



Constellation: Aries **Magnitude:** +5.9 **AM/PM:** AM

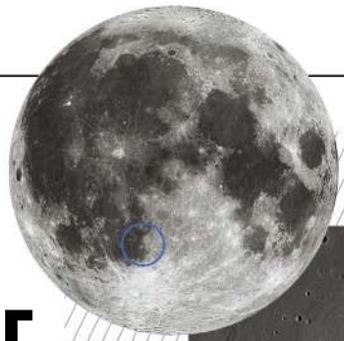
Uranus is technically a naked-eye planet this month, but the sky will be so bright through the night and before dawn that you'll need binoculars to see it. At the start of our observing period Uranus will be too close to the Sun and too low in the sky to be seen, but it will brighten and move further away from the Sun as the days pass.

NEPTUNE 04:00 BST on 6 June



Constellation: Pisces **Magnitude:** +7.9 **AM/PM:** AM

Even in a dark sky, Neptune is so faint that you need binoculars or a small telescope to see it, so looking for it before sunrise on a bright morning in May or June will be very challenging. It will help that at the start of our observing period this faraway world will be found less than a degree away from Mars, to its upper right.



MOON TOUR

RUPES RECTA: THE STRAIGHT WALL

How to find the most dramatic cliff on the face of the Moon

If you have a small telescope or a powerful pair of binoculars and look to the lower left of the great triple crater chain of Ptolemaeus, Alphonsus and Arzachel, depending on the time of the month you will see either a short, dark line or a short, bright line. Moon atlases and astronomy apps identify it as Rupes Recta. It doesn't look like much at first glance – nothing more than a dark pencil line or a white chalk scratch drawn on the Moon's ash-grey face – but Rupes Recta has another name and is one of the most famous and beloved features on the whole of the Moon – the Straight Wall.

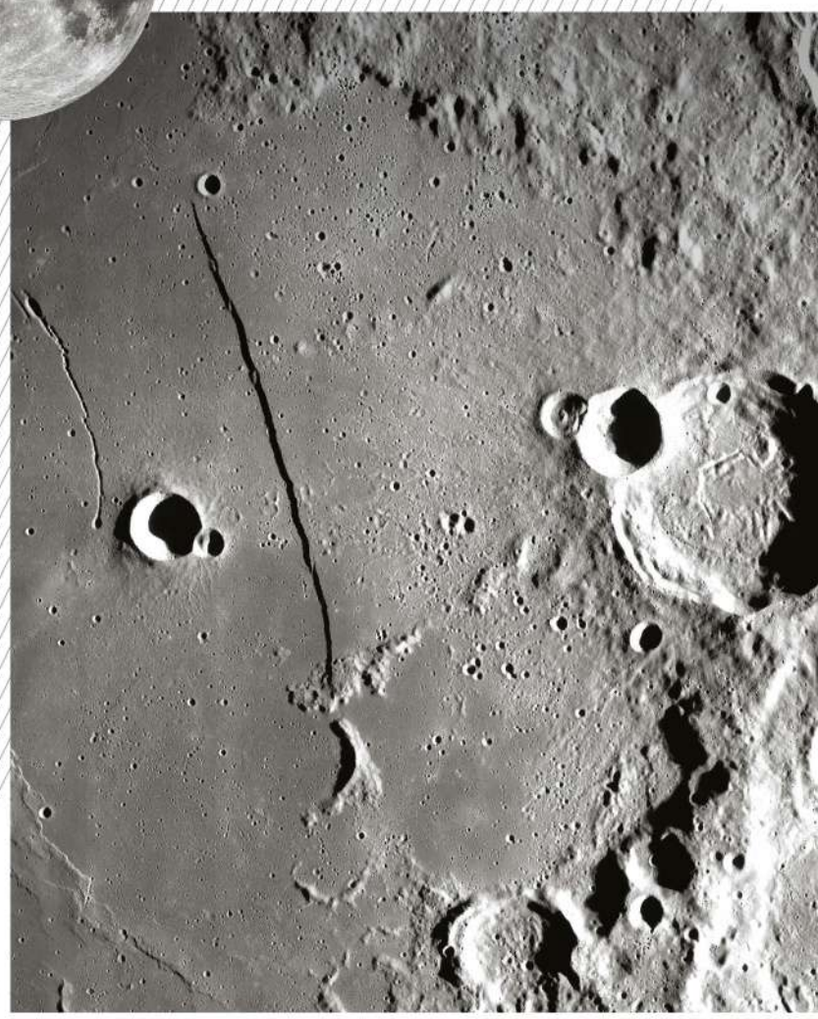
Of course, it's not actually a wall; it wasn't built by lunar labourers leaning on shovels! Rupes Recta was built by the forces of nature. It's an enormous scarp – a region where part of the Moon's surface dropped dramatically away, forming a steep cliff. The cliff itself is very narrow, barely a couple of kilometres wide and nowhere near as wide as the terraced rims of those three giant craters blasted out of the Moon to its north. It's not all that tall either: with a maximum height of around 450 metres (1,475 feet), it's roughly as tall as the London Eye, or two nuclear submarines balanced end to end. And although the Straight Wall gives the impression of being a towering cliff face, it's not. Pre-Apollo space artists depicted the Straight Wall as vertical – a frozen tsunami wave of grey lunar stone – but if you stood at the base you would see the slope rising at an angle of only 30 degrees or so.

Rupes Recta doesn't turn out to be very wide – or very high – so what's all the fuss about? The Straight Wall's remaining claim to fame is that it's very long. Stretching for more than 110 kilometres (68.3 miles) across the lunar surface, it would reach from London to the Isle of Wight if placed on Earth, or from Carlisle to Edinburgh if you prefer a more northerly comparison. That's so long it would have taken Apollo astronauts more than eight hours to trundle and bounce from one end to the other in the lunar rover, which was used on the Moon in later missions.

The Straight Wall will already be visible by 19 May, when the Moon is just at its waning gibbous phase and low in the southeastern sky before sunrise. On that morning, with sunlight illuminating it, the cliff face will be in shadow, appearing as an obvious short, dark line to the lower left of Arzachel, very close to the small, deep pit of a crater called Birt. As sunlight creeps across the Moon's face and the cliff's shadow retreats, the Straight Wall will slowly turn into a bright line which seems to sink down into the Moon, becoming harder and harder to see until it's barely visible when our natural satellite is full.

The best time to see the Straight Wall will be after midnight on 22 May, when the Moon has just passed last quarter. Now illuminated from the west, Rupes Recta's cliff face will be bathed in full sunshine, making it appear as a strikingly bright line etched into the darker surface of the Moon – looking as if it has been dug out of the ancient frozen lava flows of Mare Nubium by the tip of a knife's blade. At this time it will be visible with a good pair of binoculars, but telescopes will offer the best views – the higher the magnification the better.

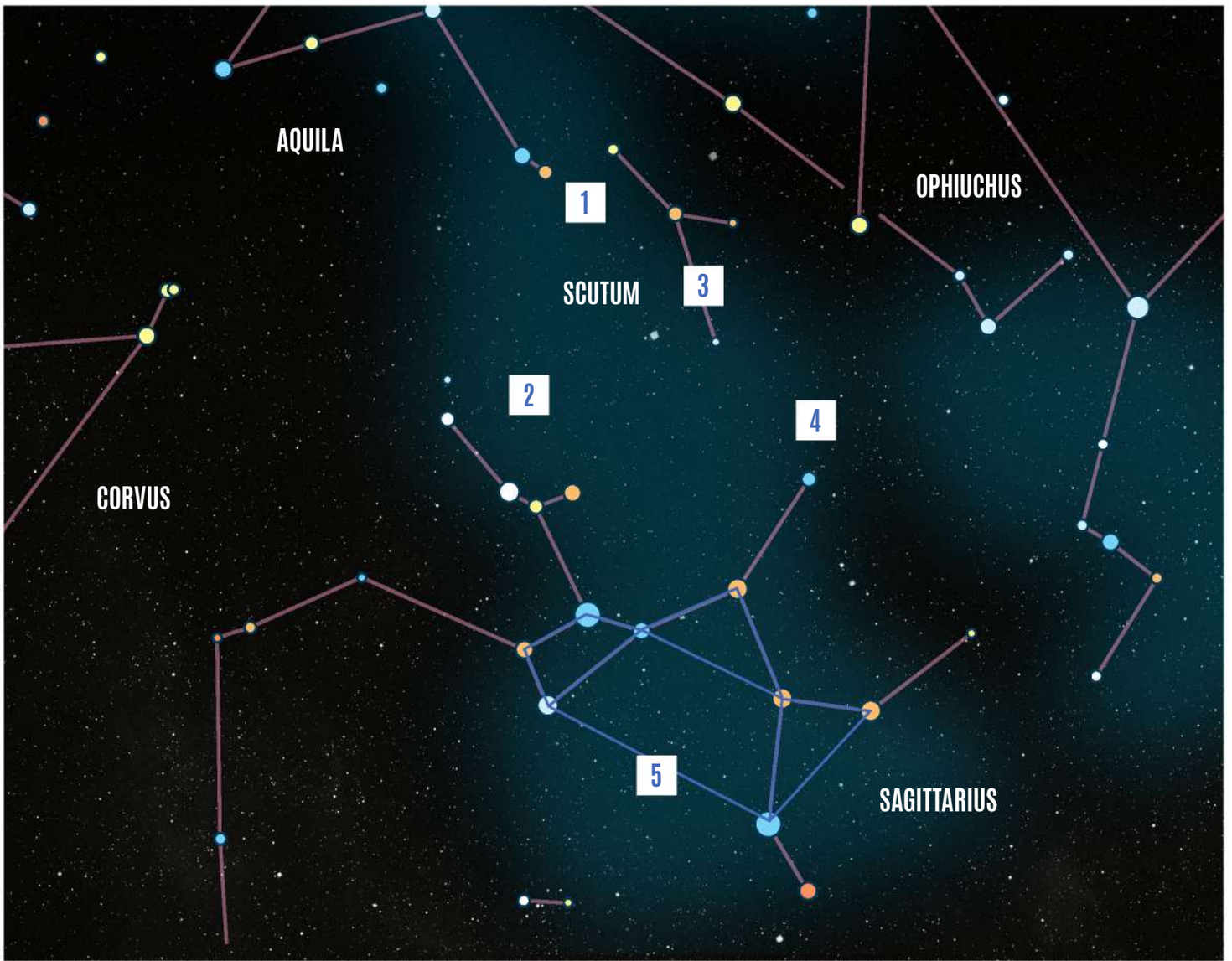
All too soon Rupes Recta will be lost from view, as local sunset plunges it into darkness. By 25 May it will be lost in shadow, hidden from our gaze until just about a fortnight later, coming back into view from 11 June. One day in the future, astronauts will surely come to the top of the Straight Wall and gaze down on the Moon's magnificent desolation from its lofty heights. Until then, we can enjoy gorgeous views of it from Earth with the most modest observing equipment.



© ESO

TOP TIP!

Rupes Recta is easiest to see when it's near the terminator – the line between lunar night and day.



NAKED EYE AND BINOCULAR TARGETS

The skies of late spring are full of amazing sights for those with no telescope

1 The Wild Duck Cluster (Messier 11)

This lovely cluster really does look like a flight of birds across the sky. Many of the stars that comprise it are brighter than 14th magnitude, with binoculars revealing a hazy spot as bright as a +6.0 star. From locations untouched by light pollution, Messier 11 can be glimpsed by the unaided eye.

2 The Milky Way

From a dark-sky site at this time of year, the Milky Way arcs across the sky from north to south. A dusty band is immediately obvious to the unaided eye, but scanning it with binoculars with even a modest magnification on a moonless night will reveal countless stars that pack your field of view.

3 Scutum constellation

Meaning the Shield, this constellation isn't particularly conspicuous, but lies in a dense part of the Milky Way. Its brightest star Alpha Scuti glimmers at a magnitude of +3.85, while its faintest star, Delta Scuti, a bluish-white giant, glows at a magnitude of +4.72.

4 Small Sagittarius Star Cloud (Messier 24)

Visible with the naked eye and really impressive in binoculars, Messier 24 is in a dense part of the Milky Way. Under good observing conditions about 1,000 stars can be resolved through binoculars with a field of view of at least two degrees at low magnification.

5 The Teapot asterism

The constellation of Sagittarius is famed for this group of stars, which create a pattern that's not too dissimilar to a teapot. Those fortunate to have good observing conditions should be able to see 'steam' billowing from the teapot's spout – this is the edgewise view into our own galaxy.

2 NGC 6207

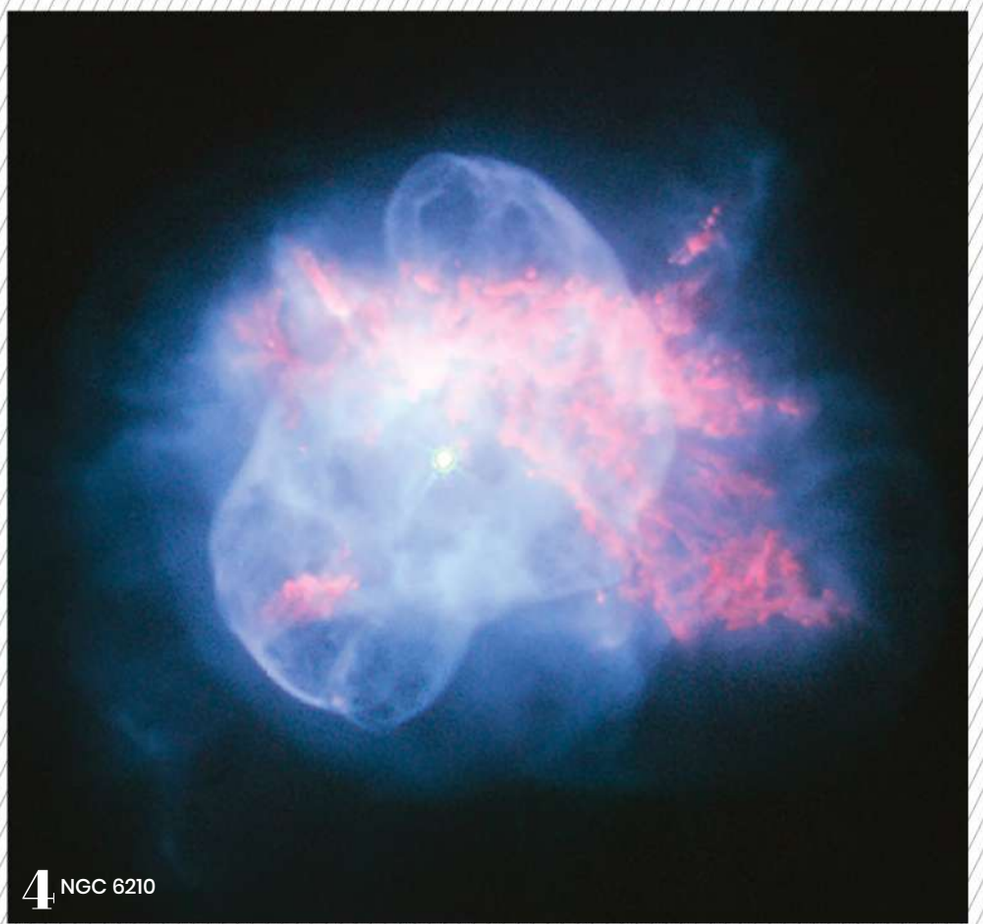
DEEP SKY CHALLENGE

HIDDEN WONDERS OF HERCULES

There's more to this constellation than Messier 13, the most beautiful globular cluster in the northern sky

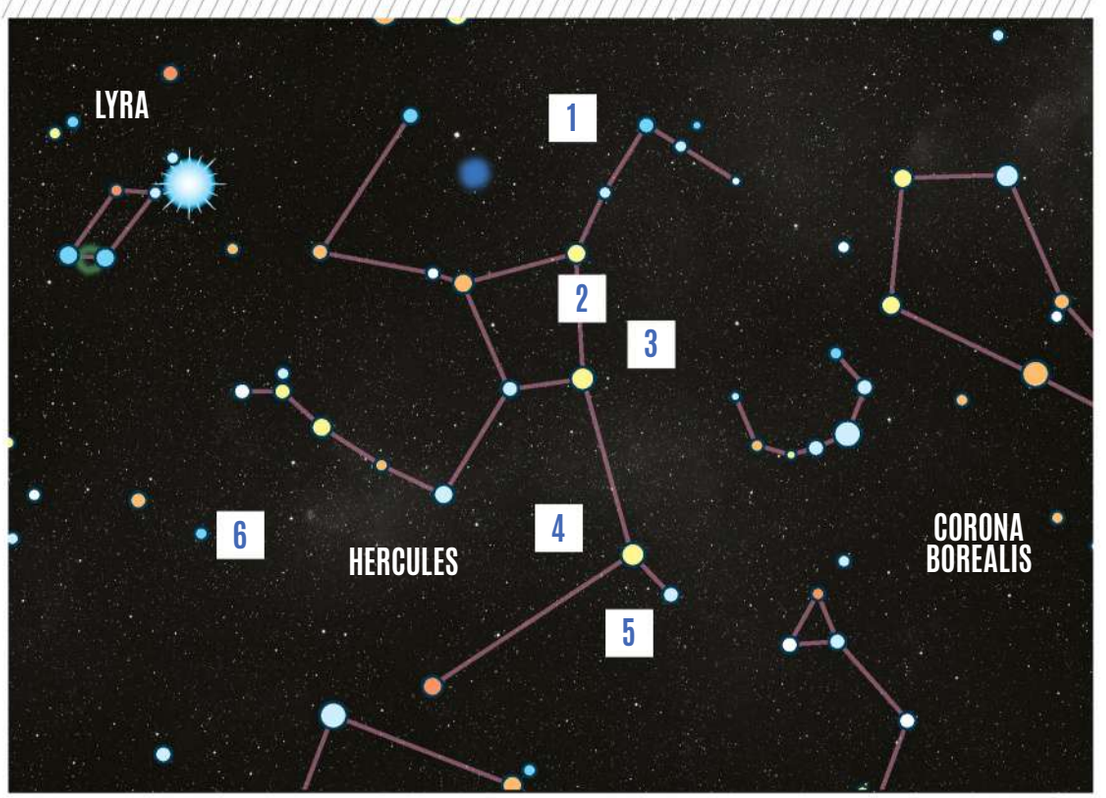
Think of Hercules and naturally you think of Messier 13, the Hercules Globular Cluster. Many observers think it is the finest globular cluster in the northern sky, and that's fair enough. It contains perhaps a million stars all packed closely together. The problem is it's so impressive it tends to hog the Herculean limelight, overshadowing everything else in that constellation. There's another problem: by the time June rolls around the night sky doesn't actually get dark for those at mid-northern latitudes until well after midnight, so if you want to see any of these underappreciated objects you'll need to stay up late or set your alarm for early in the morning. Unsurprisingly, this part of the sky, away from the glittering star clouds of the Milky Way, is poor in gaseous nebulae but rich in clusters and galaxies. All are very distant and faint, so are small in even high-power eyepieces, but the satisfaction you'll get from tracking them down makes up for their rather underwhelming visual appearance.

5 NGC 6181



4 NGC 6210

"This part of the sky is poor in gaseous nebulae but rich in clusters and galaxies"



1 NGC 6229
This ninth-magnitude globular cluster is no rival for Messier 13, but it can be resolved at high magnifications into a small, smoky ball.

2 NGC 6207
Sitting roughly 50 million light years away from Earth, in a large telescope's high-power eyepiece this 11th-magnitude galaxy is a small elongated smudge.

3 NGC 6916
You'll only see hints of this 14th-magnitude spiral galaxy's tightly wound arms through a large telescope under a perfectly clear and dark sky. It is an amazing 460 million light years away.

4 NGC 6210
This magnitude +8.8 planetary nebula's smoky ring can be seen through small telescopes, but with an eight inch or larger instrument you'll see hints of blue and green colour and the star at its centre.

5 NGC 6181
This tightly wound spiral galaxy lies 110 million light years from Earth. At +11.6, you'll need a large telescope, dark skies and high magnification to resolve its sweeping spiral arms.

6 NGC 6482
This elliptical galaxy is over 200 million light years away. At 11th magnitude, it will look like a faint smudged oval in any telescope, no matter how large its aperture is.

© NASA/ESA & Hubble Space Telescope

THE NORTHERN HEMISPHERE

Now well into spring, the heavens are alive with galaxies, star clusters and nebulae

Leo (the Lion) and its stunning array of galaxies stand proudly high above the southern horizon as darkness falls. The Leo Triplet, made up of galaxies Messier 66, Messier 65 and NGC 3628, is an easy catch for observers with telescopes with at least small to medium apertures. A variety of star clusters are visible, in particular open clusters the Pleiades (Messier 45), the Beehive Cluster (Messier 44) and the Great Globular Cluster in Hercules (Messier 13). At varying times of the night, the naked-eye planets will make their way along the ecliptic. Remember, when using this map you should use it under red light to preserve your night vision, keeping your eyes fully dark-adapted.

Messier 66

Leo and the Beehive Cluster (Messier 44)

Messier 68

Using the sky chart

This chart is for use at 22:00 mid-month and is set for 52 degrees latitude.

1. Hold the chart above your head with the bottom of the page in front of you.
2. Face south and notice that north on the chart is behind you.
3. The constellations on the chart should now match what you see in the sky.

Magnitudes

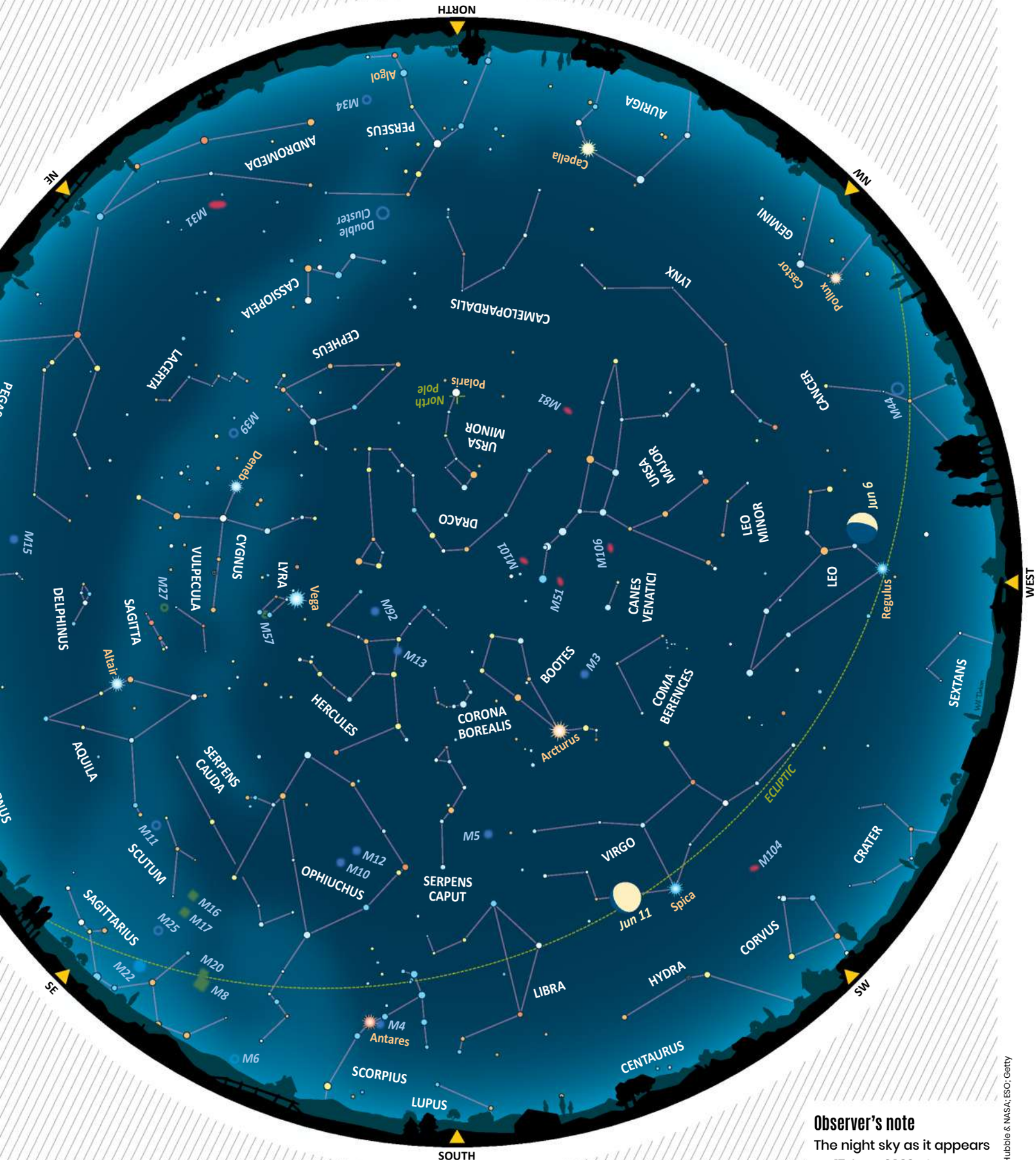
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to +0.5
- +0.5 to +1.0
- +1.0 to +1.5
- +1.5 to +2.0
- +2.0 to +2.5
- +2.5 to +3.0
- +3.0 to +3.5
- +3.5 to +4.0
- +4.0 to +4.5
- Fainter
- Variable star

Spectral types

- O–B
- A
- F
- G
- K
- M

Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



Observer's note
The night sky as it appears on 17 June 2022 at approximately 22:00 (BST)

© ESA/Hubble & NASA; ESO; Getty

ASTROSHOTS OF THE MONTH

WARREN KELLER

Location: West Virginia

Telescope: University of North Carolina-owned 16-inch RCOS Ritchey-Chrétien

"A child of the 1960s – *Star Trek*, *2001: A Space Odyssey* – I boldly went with my heroes where no man had gone before, and I never really touched down again. I began exploring the night sky at 15 years old with an eight-inch Newtonian, and I knew from the moment I received Fred Hoyle's book *Astronomy* that I would someday photograph the wonders of the skies above.

"I started out using film in 1998, and then I switched to a charged-coupled device (CCD) in 2003. I am artistic by nature, so for me it's less about the cosmology and more about the thrill of the hunt for the myriad of beautiful shapes and colours throughout the universe."

Rosette Nebula (NGC 2237)

DIPTIMAN NANDY

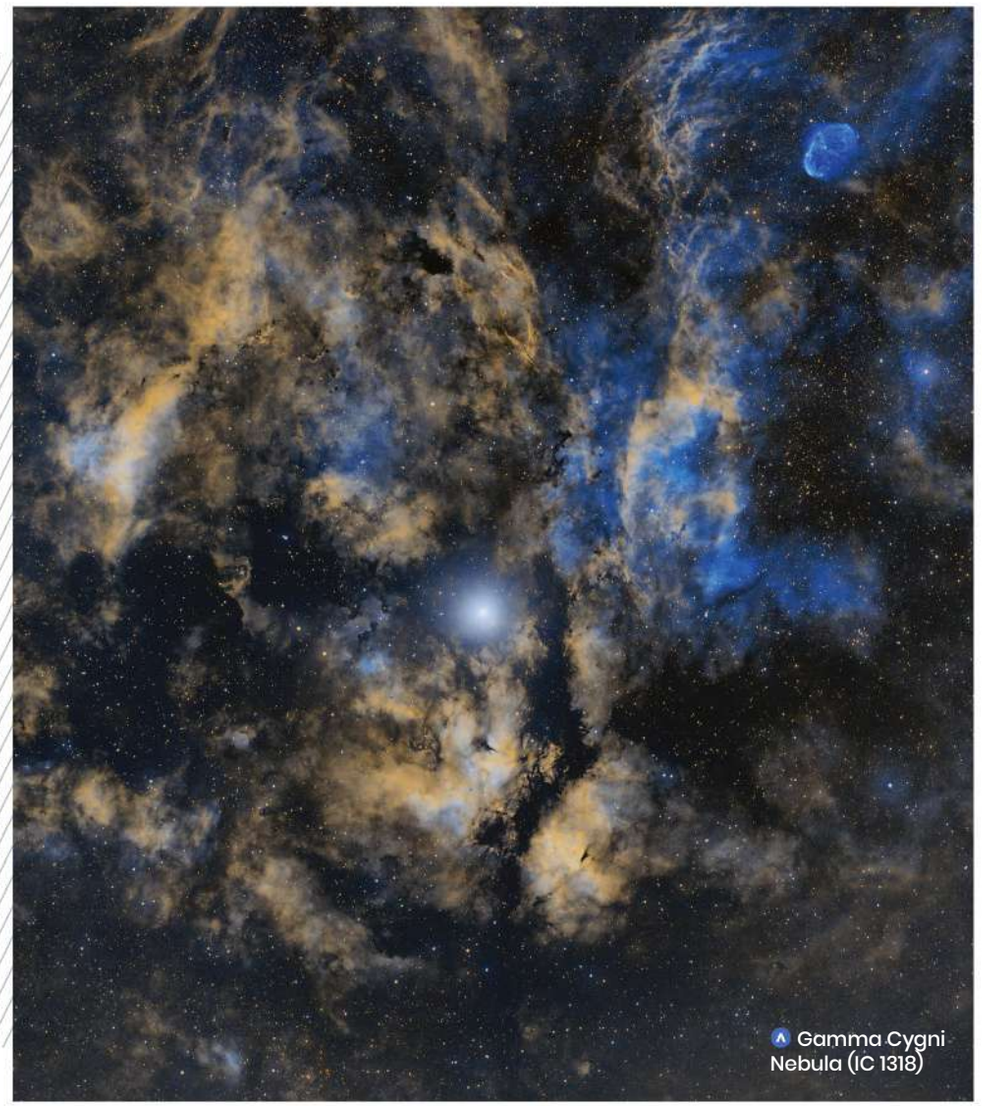
Location: Almería, Spain

Telescope: Takahashi FSQ-106EDX4

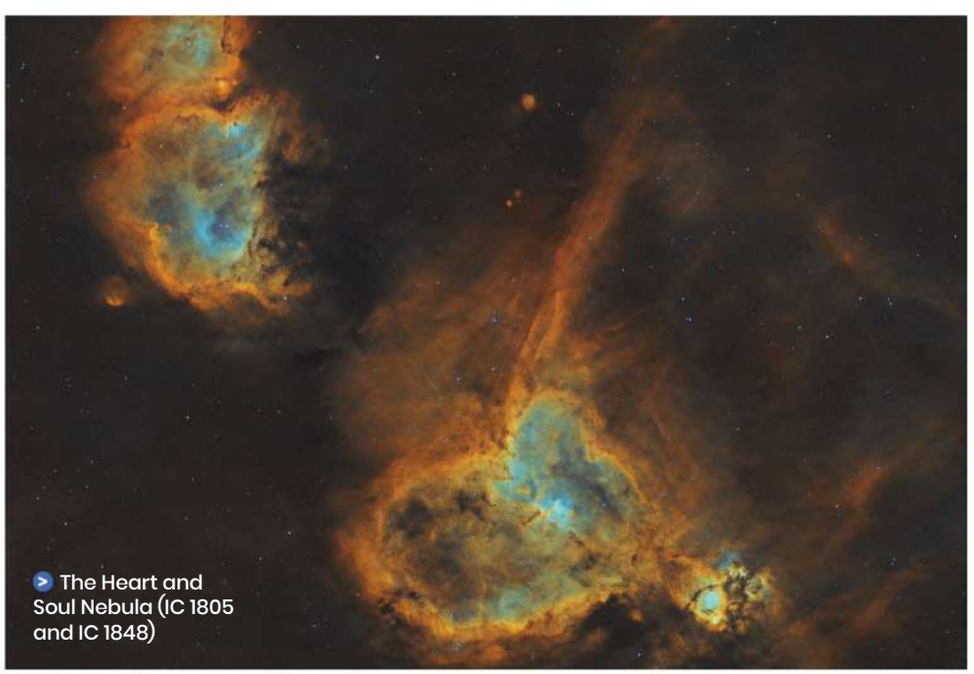
The Sadr Region – also known as IC 1318 or the Gamma Cygni Nebula – is the diffuse emission nebula surrounding Sadr (Gamma Cygni) at the centre of Cygnus' cross. The Sadr Region is one of the surrounding nebulous regions; others include the Butterfly Nebula (middle) and the Crescent Nebula (upper-right corner). It contains many dark nebulae in addition to the

"It contains many dark nebulae in addition to the diffuse nebulae"

Diptiman Nandy



Gamma Cygni Nebula (IC 1318)



The Heart and Soul Nebula (IC 1805 and IC 1848)

TERRY HANCOCK

Location: Colorado

Telescope: William Optics RedCat and QHY16200A CCD

A very wide view of the Heart and Soul Nebula (IC 1805 and IC 1848) – 7,500 light years away in Cassiopeia – using data from Grand Mesa Observatory's System 1A William Optics RedCat together with a QHY16200A monochrome CCD. This combination is giving a field of view of approximately six by five degrees. The gases (mostly hydrogen) that comprise the nebulae are being ionised by the stars within the region, and as a result the gases glow, much like a neon sign."

REVIEW

ZWO ASI183MC PRO

This CMOS camera offers high-end features in an affordable package, but how does it perform under the night sky?

Reviewed by Damian Peach

CAMERA ADVICE

Cost: £781 / $855

From: Rother Valley Optics / Amazon

Sensor: Sony IMX183CQJ-J

Pixel size: 2.4 microns

ADC: 12 bit

FPS: 19 frames per second at full frame

Cooling: 12V two-stage, -45 degrees Celsius (-49 degrees Fahrenheit) below ambient

Peak Quantum Efficiency: 84 per cent

Interface: USB 3.0

Dimensions: 7.8 by 73.5 centimetres (3.1 by 2.9 inches)

Weight: 410 grams

Choosing the best cameras for astrophotography can be a daunting task. Today we are spoiled for choice, with a huge range of different manufacturers and models to choose from. The company ZWO has been producing astroimaging cameras for a decade now, and as the years have progressed it has become one of the most popular manufacturers of affordable cameras for astrophotography.

The ZWO ASI183MC Pro camera is aimed at those looking to purchase a dedicated multipurpose camera for astrophotography. A few years back, cameras such as this would have set you back a tidy four-figure sum, but with the advent of affordable technology from Chinese manufacturers such as ZWO, the playing field has completely changed. Cameras once costing a small fortune are within reach of a much wider range of consumers.

The small but impressive camera features multiple USB connection ports

This model offers a full-colour camera with an onboard cooling system to minimise noise for long-exposure astrophotography, as well as being suitable for short-exposure lunar and planetary imaging. It also comes packaged with a variety of useful accessories to help get you up and running easily. We put the camera through its paces under the night sky, focusing the CMOS on a multitude of different targets to see how it performed.

The ZWO ASI183MC Pro comes in a compact design typical of many cameras of this type. Its small 7.8-by-73.5-centimetre (3.1-by-2.9-inch) body is of sturdy construction, featuring a multitude of ports on the rear of the camera body along with prominent cooling vents. The camera itself comes equipped with a multitude of accessories to get you started straight out of the box.

The camera connects to a PC via the supplied USB 3.0 cable, and drivers to run the camera can be downloaded from the ZWO website. We had no trouble at all having the camera up and running within a few minutes. In the box along with the camera itself comes a variety of accessories. The camera also comes in a small, padded zip bag. Also included are a multitude of different adapters, giving you options on how to connect it to your telescope or attach other accessories. On the rear face of the camera are two USB 2.0 ports for connecting accessories such as an auto-guider, which most will require for serious long-exposure work. The camera cooling system is powered by a 12V supply, which is not included with the camera but can be purchased separately.

For astroimaging, we started out by testing it on the planets. Jupiter was well placed in the night sky, coming out of a favourable opposition, so it presented a good first test subject. We attached the camera to our 14" telescope and slewed over to Jupiter. One thing to note immediately is that you'll need a UV/IR

Jupiter made an excellent planetary test subject

The cooling vents contrast against the colour of the camera body

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blocking filter for this camera, otherwise the colour will be polluted by infrared signal. For example, when imaging Jupiter the on-screen image looked pink as a result of this. Such filters are widely and easily available and are an important accessory for anyone practising astrophotography with dedicated astronomical imaging cameras such as this.

With Jupiter, since much of the field was not required, we used the region of interest (ROI) feature to crop down the captured area. This allows the camera to run at very high frame rates, desirable for imaging the planets. The camera easily ran comfortably at 100 frames per second, capturing data quickly and easily. Imaging the planets with colour cameras such as this is always good fun, as you can often see many details and colours on their discs.

You can also use the ZWO ASI183MC Pro as a mono camera. We attempted some near-infrared captures of Jupiter through an IR685nm filter, and again the camera performed superbly for the task. Many modern Sony CMOS sensors, such as the one used in the ASI183MC Pro, have great sensitivity in the near-infrared wavelengths, which is ideal for imaging the planets. After shooting Jupiter, we then turned to Saturn – a more challenging planetary target. Again the ZWO ASI183MC Pro performed very well, producing good quality photos.

Next up came the tests for deep-sky imaging. For this we decided to wait for a decent clear and moonless night. For the initial tests we decided to try imaging with the camera without using the cooling system to see just how well it would perform 'out of the box', so to speak. We decided to shoot a series of 60-second exposures of Messier 42 – the famous Orion Nebula – with the camera attached to a small refracting telescope. Even using short exposures such as this, a tremendous amount of detail was recorded. The familiar red wisps of nebulosity fanning out from the core of the nebula are apparent, and the whole scene looked very impressive. By stacking several such images together, we were able to produce a nice, smooth result to be processed using image-processing software such as Photoshop.

Over the course of around an hour, we took lots of exposures of the nebula to stack and process later on The result was certainly impressive, especially given the camera cooling system wasn't used. We did, however, apply a dark frame correction to the image to remove hot pixels. The data output from the camera is remarkably clean.

We then decided to fire up the camera cooling system and try a few shots using it. The cooling system is only required if you are going to use the camera for long single exposures of several minutes. In this

© Damian Peach

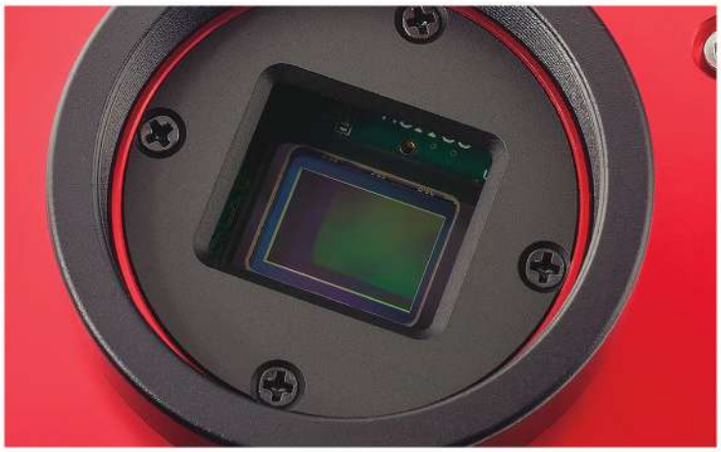
instance it does make a notable difference, reducing noise across the image. Overall the performance of the ZWO ASI183MC Pro was impressive. It easily produced good, clean images of brighter deep-sky targets and operated throughout the imaging sessions without any issues.

Operating the ZWO ASI183MC Pro camera is a straightforward process. Drivers can be downloaded from the ZWO website, as can camera control software which you can use to operate the camera, called ASI Studio. The camera is also supported by other third-party software which also works extremely well to run the camera. Programs such as FireCapture will run the ZWO cameras and are available online to download for free.

The camera itself is powered directly from the USB connection. A separate power supply is only needed if you wish to run the camera cooling system, but this is only really needed for very long-exposure work. Once it's connected to your PC, you'll see a live preview on screen. On the PC we tested the camera on, it easily achieved the quoted 19 frames per second rate at full-frame running. For those looking to use the ZWO ASI183MC Pro for long-exposure work, you'll need to get a suitable 12V power supply to run the camera cooling system. ZWO offers suitable options for sale, or a third-party one will do, which is what we used for the purpose of this review.

For those looking to take their first steps in buying a dedicated astronomical-imaging camera without the hassle of using a mono camera, you can't go wrong with the ZWO ASI183MC Pro. It's a great multipurpose imaging camera that can produce excellent images of both planetary and deep-sky targets. It's also incredibly easy to set up and use, which is a major bonus, especially for newcomers.

For the price the ZWO ASI183MC Pro offers some impressive specs, and is far more affordable than equivalent high-end mono astronomical-imaging cameras of similar resolution. No product is perfect, however, and this is no exception. It would be good to see a power supply unit and UV/IR blocking filter included as part of the standard package, as these are essential accessories – the filter especially. Another point worth mentioning is how the camera compares to a similarly priced DSLR. Image quality is similar, and the DSLR can be used for conventional photography too, so this is something worth considering.



The front of the camera features the imaging sensor

Messier 42 – 20 60-second exposures were stacked for this view

© Damian Peach

"The camera easily ran comfortably at 100 frames per second, capturing data quickly and easily"

FOR

- Large CMOS chip
- Cooling system
- Clean data quality
- Included accessories are useful

AGAINST

- Heavy for its size
- Competing-level DSLRs produce similar image quality
- Experience with dedicated astrophotography cameras is needed
- Power supply unit for the cooling system isn't included

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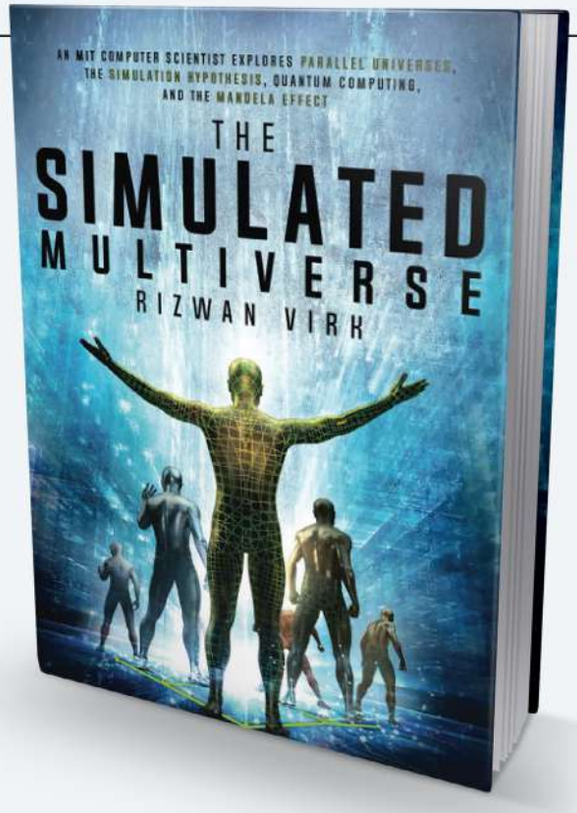
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2

3

For your home

Alien Abduction Lamp

Cost: £99 / $129
From: abductionlamp.com

1 This lamp seemingly hovers over your tabletop as the light beam underneath captures an unsuspecting cow, while little glow-in-the-dark aliens peer out. There are four different functions on the Alien Abduction Lamp: off; cockpit only, where the cockpit light pulses and phases through green and yellow lights; beam only, which features a steady glow from the bottom of the lamp and all on, where the cockpit pulses and phases while the beam glows steady. The flying saucer is made of steel, with a black-pearl finish.

For bookworms

The Simulated Universe

Cost: £9.99 / $14.95
From: Waterstones / Barnes and Noble

2 Bestselling author Rizwan Virk explores the wild notion of a complex multiverse. Virk offers up mind-scrambling dissections of provocative topics like parallel universes, infinite timelines, quantum computing, alternate simulated realities, contorted definitions of space and time and the Mandela effect – a phenomenon in which a minority of the population recalls memories of past events different from the consensus. It's a fascinating explanation of our world that might shake the foundations of your digital reality, but in a digestible style.

For observers

Fenix PD35 Tactical Edition

Cost: £69.95 / $79.95
From: Fenix

3 Fenix is an incredibly reliable brand that works with rescue services on some of the flashlights they use in mountainous areas where there's no light to speak of except what you bring with you. However, the PD35 isn't necessarily the most powerful device the brand has made. At 1,000 lumens, it still provides a level of customisation in light modes that makes it worth considering. It's small and lightweight, so you can throw it in a bag without even noticing it's there. You can use any of its beams to show you the way through dark paths with ease.

4

"Play this beautiful, brightly coloured board game solo or with up to three of your friends"

5

6

For fun

Black Angel

Cost: £44.99 / $79.99
From: Pearl Games

4 As resources dwindle, in a desperate attempt to save the human race the nations of Earth band together to create Black Angel – a gigantic, technologically advanced spacecraft that's controlled by artificial intelligence to safely transport human genetics across the galaxy. Play this beautiful, brightly coloured board game solo or with up to three of your friends as you take on the role of the AI workers whose mission it is to get the precious cargo to its new viable home on a journey that will last about two hours in real life.

For astrophotographers

Sigma 14mm f/1.8 DG HSM Art

Cost: £1,399 / $1,599
From: Sigma

5 The build quality is exceptional and the lens is weather-sealed. The fixed focal length and extra-wide field of view are also ideal for capturing expansive vistas. Performance in the field is nothing short of stunning. Stars appear pin-sharp, even when the aperture is opened up to its impressive f/1.8 maximum, though stopping down the aperture a little will improve the coma that appears towards the corners of the image frame. Chromatic aberration is well controlled when shooting at wide apertures and image distortion is handled equally well.

For gamers

Astro Bot Rescue Mission

Cost: £34.99 / $39.99
From: Playstation

6 When thinking of games that lend themselves to the virtual-reality space, third-person platformers are certainly not the first to come to mind. *Astro Bot Rescue Mission* works by not putting you in the position of the titular robot, but instead as its human companion, ever watching over its adorable antics. Astro Bot knows when you are looking at it. It looks at you and cheers you on. It takes you through underwater worlds and lush jungles and the whole time acts as though it is beyond ecstatic to have you by its side.

HEROES OF SPACE

ENRICO FERMI

The physics pioneer best known in the space world for his famous Fermi paradox

A gifted teen, Fermi won a scholarship to the prestigious Scuola Normale Superiore University in Pisa with an entry essay so impressive it would have been commendable for a doctorate. Fermi was even asked by his teachers to organise his own seminars on quantum physics, as there was nothing they could teach him. Fermi's skills meant he was largely self-taught, and he graduated with honours in 1922. He went on to win a Rockefeller fellowship, studying under renowned physicist Max Born in Germany, where he also met Albert Einstein. Between 1926 and 1927, Fermi and English physicist Paul Dirac developed new statistics known as Fermi-Dirac statistics, concerned with subatomic particles that obey the Pauli exclusion principle. These particles, now known as fermions, were a monumental contribution to atomic and nuclear physics.

Continuing to impress and excel, Fermi was elected professor of theoretical physics at the University of Rome, gathering a team of talented students. It was at Rome that he began his most important work, beginning to look into the field of nuclear physics. In 1934 he discovered that nuclear transformation could occur in most elements. One of the atoms Fermi split was uranium; this led to the phenomenon of slowing down neutrons, which in turn led to the creation of new elements beyond the periodic table.

Fermi was awarded a Nobel Prize in 1938 for his contributions to physics, using the prize money to escape with his family to America. Once safely in the United States, Fermi continued his work as professor of physics at Columbia University, where his experiments led to the first nuclear chain reaction. As World War II broke out, Fermi was employed as a major part of the team that developed the atomic bomb.

Fermi became a full American citizen in 1944, working with a variety of distinguished scientists such as James Cronin and Jack Steinberger. While working in America he began to redirect his attention away from nuclear physics and towards high-energy particle physics. Fermi dedicated a lot of his time to studying the origin of cosmic rays, also investigating magnetic fields in the arms of a spiral galaxy. He also raised a question now known as the Fermi paradox: "Where is everybody?" This famously asks why no extraterrestrial civilizations have been found and no contact made. Sadly by 1954 Fermi was suffering with incurable stomach cancer, and he died in his sleep aged 53.

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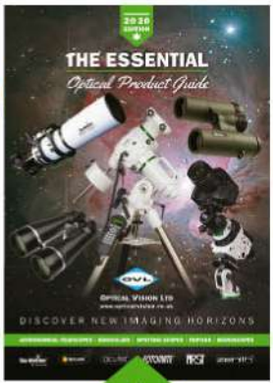

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